RECORDS

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CORRIGENDUM.

OTOLITHS FROM THE MIOCENE OF BURMA, ERRONEOUSLY DESCRIBED AS A NEW GENUS: *TWINGONIA*, PASCOE (PP. 138, 139, Pl. 18, OF THE PRESENT VOLUME).

The specimens figured on Plate 18 of the present Volume, with the suggestion that they perhaps represent a new genus of foraminifer, and described as "*Twingonia*" are, in reality, fish otoliths. The specimen, represented in fig. 1, shows with the utmost distinctness the auditory sulcus characteristic of these organs. The figure exhibits only the outer side of the specimen, and conveys a wrong impression of the shape of the surface, which, instead of being uniformly convex, as the shading would suggest, is irregularly warped, and partly concave towards the upper and lower margins, and is ornamented, near the upper margin, with perpendicular ridges of which no trace appears on the figure. The opposite side, bearing the sulcus, is convex.

We are indebted to Mr. Bankim Behari Gupta, Museum Assistant, for detecting the true nature of these fossils, which came into his hands as he was storing them in the Museum collection. A closely related form had already been noticed and figured by Dr. Noetling (*Pal. Ind.*, New Ser., Vol. I, Mem. No. 3, Pl. XXV, figs. 19, 19*a*), but the ornamentation of the outer surface is somewhat different, while the inner surface is much weathered. Mr. Gupta has compared Mr. Pascoe's specimen with the figures in Dr. Koken's monographs (*Zeitschr. deutsch. geol., Ges.*. Vol. XXXVI, 1884; Vol. XL, 1888; Vol. XLIII, 1889), but it does not agree exactly with any of them, though the sulcus is very similar in the case of figs. 7 and 8 of Pl. XII, in Vol. XXXVI (1884).

According to Mr. Gupta, the specimens illustrated in figs. 4 and 5, Pl. 18 of the present volume, also described as "*Twingonia*," represent another species of otolith not unlike the one reproduced in fig. 12, Pl. XII, of one of Dr. Koken's monographs (Vol. XXXVI, 1884). The outer concave side alone is visible in the specimens so far available, and Mr. Gupta has not yet been able to develop any of the specimens in such a manner as to obtain a view of the sulcus.

[E. W. VREDENBURG

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PETROLOGICAL STUDY OF SOME ROCKS FROM THE HILL TRACTS, VIZAGAPATAM DISTRICT, MADRAS PRESIDENCY. BY T. L. WALKER, M.A., PH.D., *University of Toronto,* and W. H. COLLINS, *Geological Survey of Canada.* (With Plates 1, 2, and 3.)

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I.—GENERAL STATEMENT.

THE material for the study of which the results are presented in the present paper was collected by Mr. C. S. Middlemiss, Superintendent of the Geological Survey of India, during the field seasons 1901-02 and 1902-03, while conducting the geological survey of the Hill Tracts of Vizagapatam district. The suite of specimens appears to represent a metamorphic series of rocks resulting from various stages of mingling of ultra-basic igneous and of argillaceous sedimentary materials. We think that the evidence contained in this

paper justifies us in regarding these interesting rocks containing sapphirine, cordierite, spinel, sillimanite, and hypersthene as having been produced by the action of spinel iron-ore ultra-basic igneous border products on khondalite rich in sillimanite, representing the metamorphosed sedimentary mantle which frequently overlies the great igneous mass which forms the northern part of the Eastern Ghauts.

Our thanks are due to the Director of the Geological Survey of India for the opportunity of working over this very interesting suite of rocks, to Messrs. Middlemiss and Vredenburg for maps and notes regarding their field characteristics and distribution, and to Principal Galbraith, School of Practical Science, Toronto, for his assistance in the preparation of microphotographs.

The chemical analysis reported in this paper and also those parts dealing with the charnockites and with the end members of the sapphirine-bearing series are entirely the work of Mr. Collins. In addition to this he has contributed to most of the other sections of the report.

II.—SAPPHIRINE-BEARING ROCKS AND THEIR ASSOCIATES.

The present section of this paper deals with a highly interesting series of rock specimens collected during the season of 1902-03 in the district of Vizagapatam, by Mr. C. S. Middlemiss, who has already described the occurrence of sapphirine in this area.[1]

Vizagapatam, Kalahandi, Jeypore, Ganjam, and Orissa contain among them a petrological province whose geological characters have been established through the investigations of the Geological Survey of India. Operating in Ganjam in 1899-1900, Mr. F. H. Smith[2] found the western portion of that region to consist of an igneous complex associated closely with a series of metamorphosed sediments. The igneous rocks, which he considers as forming "the main foundation of the whole of the Ganjam district," consist of "garnetiferous granites and granulites" with "pegmatite, biotite gneiss, and hypersthene granulites, varying from acid to almost basic forms and representing the charnockite series." "The crystalline schists evidently represent a more or less metamorphosed series of ancient sedimentary rocks—the commonest form is a quartz-garnet schist always

[1] C. S. Middlemiss, Note on a sapphirine-bearing rock from Vizagapatam district, *Rec. Geol. Surv. Ind.*, XXXI, 1904, 38 - 42.

[2] F. H. Smith, *Gen. Rep., Geol. Surv. Ind., 1899-1900.*

rich in sillimanite." Much crushing and folding is spoken of, large masses of the para-schists being found as bands within the igneous rocks.

One of the authors of this paper, Dr. T. L. Walker, working in the neighbouring mountain region of Jeypore zemindari,[1] found igneous rocks varying greatly in acidity which he believes to be identical with charnockites.[2] The following season in the adjacent State of Kalahandi [3] charnockites were again found, which apparently together with those of the previously studied Ganjam and Jeypore districts, formed part of a single great massif. With regard to the sillimanite bearing schists which appear to be invariably associated with the underlying complex, he wrote :—" Apparently these isolated outcrops are remnants of a once continuous arch of altered sediments covering the great igneous massif of charnockites and associated rock which extends almost from the Godavari to the Mahanadi."

The massif referred to by Dr. Walker extends as an ellipse 250 miles long and 60 wide in a direction parallel to the adjacent coast of the Bay of Bengal, and includes portions of the states and districts mentioned above. Together with its covering of metamorphosed sediments it forms a denuded plateau 3,000 or 4,000 feet in altitude which is completely carved into hills and valleys, the summits of the latter standing at approximately equal elevation.[4]

The rocks here considered were collected from a small area that may be defined as lying near the villages of Gangrez Madgul, Ontali, and Pader in Madgul taluq, Vizagapatam district, and some distance within the south-eastern border of the charnockite massif. Pader lies in north latitude 18° 4′ and east longitude 82° 42′ 30″. Large neighbouring areas of charnockite occur, but in the immediate vicinity of these villages the predominant formation is the khondalite or sillimanite, bearing para-schists through which run narrow, interrupted bands of gneissoid granite lying parallel to one another and to the major axis of the massif. These bands are probably the exposed crests of folds in the igneous foundation from which the sedimentary covering has been removed by denudation. The specimens were taken in the

[1] T. L. Walker, *Gen. Rep. Geol. Surv. Ind., 1899-1900.*

[2] T. H. Holland, *Mem. Geol. Surv. Ind.,* XXVIII.

[3] T. L. Walker, Geology of Kalahandi State, *Mem. Geol. Surv. Ind.,* XXXIII.

[4] F. H. Smith, *loc. cit.*

vicinity of these bands, and in a number of cases from their extremities.

(*a*) Ultra-basic spinel-bearing rocks.

Specimen 16·174, obtained near Panasput, is a massive black rock of specific gravity 4·02, resembling a magnetic iron-ore in the hand specimen. Upon microscopic examination, however, it is found to consist of green spinel and magnetite with accessory quantities of biotite, sapphirine and a few grains of a colourless, highly refracting mineral. Spinel is the predominate constituent and occurs as large, irregular, isotropic grains of deep green colour crowded with particles and feathery aggregates of magnetite. In the immediate vicinity of each magnetite particle the spinel is paler and more transparent than elsewhere. (Pl. 2, fig. 2.) Occasionally the iron-ore inclusions are rudely idiomorphic. Biotite occurs in well-formed plates, possesses a strong brown pleochroism, and is quite free from signs of crushing or strain. Sapphirine is subordinate in amount, appearing as small rounded grains of deep blue colour and strong pleochroism. Scattered sparingly through the sections are minute, sometimes nearly hexagonal, particles of limpid transparency, high relief and bright polarisation tints which may be corundum.

Upon chemical analysis this rock yielded the results given in column V of a subsequent page. Both mineralogically and chemically it bears considerable resemblance to the small group of igneous rocks termed ultra-basic segregations, rocks of low acidity found in association with gabbros and norites. For the sake of comparison, an analysis of a segregation of this character found in association with gabbro in Finland is cited in the adjacent column VI. The low percentage of silica and large quantities of TiO_2 and iron oxides are characteristic of both. G. H. Williams has described [1] rocks of similar nature occurring about the margins of a norite area in New York State.

As recorded by Mr. Middlemiss, who collected this specimen, it was obtained near the contact between the charnockites and khondalites, hence, if igneous in origin, it must be related to the former. In his study of the charnockites T. H. Holland has represented the extent of magmatic differentiation by creating four divisions according to acidity, as represented by the analyses quoted in columns I to IV.

[1] G. H. Williams, *Am. Jour. Sc.*, XXXIII, 1887.

Accompanying this decreasing acidity is a change in the mineralogical composition; quartz and felspar successively diminish and disappear, to be replaced by pyroxenes, olivine, and spinel. Consequent to this the specific gravity rises from 2·67 to 3·37. The principal features of chemical variation are the decreasing percentages of silica and accompanying increases in iron oxides, magnesia, and alumina.

From a rock possessing a specific gravity of 3·37, composed of hypersthene, augite, iron-ores, olivine, and spinel, and the chemical compositions given in column IV, to a rock such as 16·174 is a longer step than between any consecutive pair of types given by Mr. Holland. However, this gap is bridged by another specimen, 16·172. This consists of pyroxene, spinel, and biotite, with smaller amounts of sapphirine, sillimanite, and iron-ores. Its structure is that of a massive rock and its density 3·50. The chemical composition has not been determined, but may be considered from mineralogical evidence and density as intermediate between those given in columns IV and V.

That both 16·172 and 16·174 are related to the charnockites is further suggested by the optical likenesses of their pyroxenes to those of the characteristic charnockites. On the contrary, the surprising richness in alumina and the presence of sapphirine and sillimanite, which are unknown in pure charnockites, do not agree with this conception. In the following paragraph reasons will be given for considering them basic and ultra-basic members of the charnockite series that have been modified through contact action with the aluminiferous body now to be described.

(*b*) Sillimanite schists.

Specimen 16·173 is a light greyish brown, granular rock composed very largely of well-crystalllized silimanite. Scattered irregularly throughout this paler body are fragments of black rock material identical with the previously described spinel rocks. The hand specimen is imperfectly schistose; its density 3·31. The sillimanite exists as small square prisms of grey brown colour, but colourless in thin sections. Though usually devoid of pleochroism, some sections exhibit faint change of tint in polarised light. Cross sections are sharply rhombic with angles of nearly 90° and possess one series of distinct cleavage planes running diagonally. In all observed cases the extinction direction was inclined towards these planes, which must be regarded as pinacoidal, and thus do not seem to possess the rhombic character ascribed to sillimanite. Longitudinal sections appear

full of delicate rod-like inclusions arranged parallel to the vertical axis. The specific gravity of the mineral is close to that commonly found for sillimanite.

Neglecting the included fragments of spinel rock which are apparently not original constituents of this schist, the remaining material is almost altogether sillimanite, and would yield analytical results resembling a composition of sillimanite itself, *i.e.*, a body low in silica, alkalies, lime, and iron, but rich in alumina, thus essentially characteristic of sedimentary bodies. In the immediate locality where these specimens were obtained are the khondalites, regarded generally as metamorphosed sediments and distinguished by the presence of sillimanite. In all likelihood 16·173 is a variety of khondalite peculiarly rich in sillimanite.

(*c*) Intermediate rocks rich in sapphirine and spinel.

The relationship between the above two groups is well indicated in the composite specimen 16·171. It consists of sillimanite schist and black spinel-bearing rock in actual contact, these forming opposite ends of the hand specimen. The sillimanite material contains a larger proportion of the dark fragments than 16·173. Thin sections of this dark material show it to differ from 16·174 and 16·172 only in the proportions of its mineral constituents. Sapphirine is the predominant component, forming large, irregular grains rarely exhibiting a partial crystal outline and containing cubic or rounded inclusions of spinel. Biotite with pleochroism as described for 16·174 is in considerable quantity and shows crushed edges and undulatory extinction. In small patches and never in contact with spinel are transparent, idiomorphic crystals of sillimanite. Spinel is comparatively subordinate. Magnetite grains lie scattered among the coloured minerals.

Specimens 15·808 and 16·168 (both from the same rock-mass) differ from the dark portion of 16·171 only in being schistose and in minor details, so that an analysis of the latter given in column VII fairly represents the group. A comparison with the analysis of 16 174 and the inferred composition of 16·173 shows that all its constituents lie intermediate in amount or that the same chemical result might be obtained by analysis of a mixture made from sillimanite schist and ultra-basic charnockite materials in certain proportions. The union of these substances has apparently been brought about in nature through the absorption of an already deposited aluminous sediment

by an intruded basic charnockite magma. The basicity of this magma has varied from point to point. Specimen 16·168 has resulted from a more acid intrusion than 16·171, since the former bears a considerable amount of pyroxene and less iron-ore vestiges of the absorbed matter not assimilated remain in the form of sillimanite crystals. The most noticeable feature, however, has been the replacement of the predominant spinel by sapphirine. The general result has been a metamorphic zone between the charnockites and khondalites characterised by the presence of sapphirine.

Specimens 15·808 and 16·168, which are from the same rock-mass, belong to this zone, and it will now appear that 16·174 and 16·172 cannot be regarded as pure igneous forms, but, as indicated by their high alumina content and the presence of sapphirine, also belong to the metamorphic zone. However, modification has not proceeded far in these cases and the original igneous characters remain sufficiently distinct.

-	I.	II.	III.	IV.	V.	VI.	VII.
SiO_2 .	75·54	63·77	53·38	46·86	3·60	4·08	35·90
TiO_2 .	...	..	...	...	4·57	14·25	...
Al_2O_3 . .	13·75	16·30	19·38	9·80	45·97	6·40	32·91
FeO .	4·99	7·49	15·39	16·35	40·23	34·58	9·16
Fe_2O_3 . .						33·43	
MgO . .	·69	2·49	2·79	18·08	7·36	3·89	21·40
CaO . .	·94	6·33	7·68	9·57	·92	·65	...
K_2O . .	3·34	1·21	...	...	..	·15	...
Na_2O .	1·55	3·68	...	...	...	·29	...
H_2O . .	·28	...	..	·67	...	1·32	·60
MnO . .	...	..	...	...	..	·45	·40
Cr_2O_3 . .	...	...	.	...	...	·20	...
P_2O_5 . .	...	...	...	...	...	·02	...
TOTAL .	101·08	101·27	98·62	101 33	102·65	99·71	100·37

I, II, III, and IV.—T. H. Holland, *Mem. Geol. Surv. Ind.*, XXVIII.
V.—Analysis of rock No. 16·174.
VI.—Peterson, *Geol. Foren. Ford.*, XV, p. 49.
VII.—Analysis of rock No. 16·168.

The mineral association found in the above described metamorphic zone is an unusual one and some attention was given to the detailed study of the different species.

Sapphirine occurs everywhere throughout the zone in the form of irregular or rounded translucent grains of deep blue colour. Only two fragments with partial crystal outline have been observed. One of these seen in thin section possessed two rectilinear edges,—orthopinacoidal and a prismatic. Twinning was not observed. Most sections are traversed by a single distinct series of cleavage lines parallel to the clinopinacoid, also by heavy irregular cracks.

Optically the mineral behaves like members of the monoclinic system. The optic plane lies in the clinopinacoid and the extinction angle is about 15°. This latter was determined by means of acicular or sharply cubic inclusions of spinel whose edges coincide with the vertical and orthoaxes: the maximum inclination of these with the direction of extinction was 15°. Sections normal to the acute bisectrix show, in convergent light, a biaxial inclined interference figure: the same sections when tested with the quartz wedge indicate a negative optical character. In parallel polarised light they remain deep blue, changing only from navy to Berlin tints: prismatic and pinacoidal sections vary from deep blue to greenish orange. The birefringence is low, the relief about equal to that of augite. Suitable specimens for determining values for α, β and γ and for the optic angle could not be obtained. The accompanying diagram illustrates the optical character.

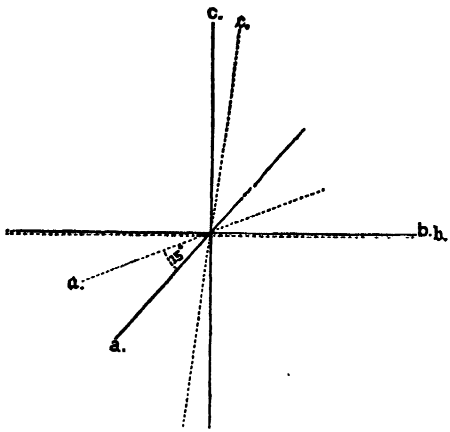

FIG. 1.

Specimen 16·168 was crushed, sifted, and the sapphirine particles separated by means of a supersaturated Klein's solution. Thus a quantity of 10·5 grammes was obtained, which, after treatment with hydrofluoric acid to remove any thin scales of adherent mica, was examined under the microscope. The specific gravity was determined to be 3·542 by using a pycnometer and the entire sample. Its hardness lies between that of quartz and topaz.

Chemically sapphirine is resistant and shows no sign of natural alteration. It is unattacked by acids except hot hydrofluoric, and then only when in a finely pulverised condition and after prolonged digestion. It is slowly decomposed by alkali carbonates, but readily by fusion with potassium bisulphate or microcosmic salt. The average of duplicate analyses is given in column VI below. Of the other analyses cited, VII is of material from the same rock, while the remainder relate to sapphirine from Fiskernäs in Greenland. The Indian specimens seem to possess relatively higher percentages of iron oxides and less of magnesia. Corresponding to this chemical difference is a noticeable variation in physical properties. The Fiskernäs sapphirine exhibits a less intense pleochroism, varying from pale blue to yellowish green. Also its specific gravity as given by Ussing is considerably less.

	I.	II.	III.	IV.	V.	VI.	VII.
SiO_2 . .	14·3301	14·86	14·76	12·95	12·83	14·56	12·55
Al_2O_3 .	63·3036	63·25	63·28	64·44	65·29	60·49	67·06
Fe_2O_3 . .	4·0092 (with FeO)	1·99	1·65	1·66	·93	7·65 (with FeO)	16·21
FeO . .					·65		
CaO . .	·0375	...	...	...	...	..	·17
MgO . .	16·9683	19·28	19·75	19·83	19·78	17·13	3·97
Loss . .	·4920	...	...	·34	·31	·56	·25
MnO . .	·052	...	...	...	...	...	...
TOTAL .	100·0000	99·38	99·44	99·22	99·79	100·39	100·75

I.—Stromeyer, Untersuch über die Mischung. d. Min., I, 391.
II.—Damour, Zeit. für K., XV, pp. 598—615.
III.—Schluttig „ „ „ XIII, p. 74.
IV.—Lorenjez, Meddelelser on Greenland, VII, p. 15.
V.—Ussing, Zeit für K., XV, pp. 598—615.
VII.—Middlemiss, *Rec. Geol. Surv. Ind.*, XXXI, Pt. I, p. 40.

Spinel.—This mineral is a prominent constituent in the sapphirine schists at Fiskernäs and constantly found in those of Vizagapatam. It is recorded in the norite members of the charnockite series and occurs only in those metamorphic rocks that have had an igneous source. In the neighbouring modified khondalites it appears to have been introduced in a solid condition by mechanical movements and cannot be regarded as native to those para-schists.

Except as cubic inclusions in sapphirine, it exhibits no crystal form, occurring always in large irregular grains, which seem to have crystallized at the same time as the magnetite particles with which it is crowded. (Pl. 2, fig. 2.) By transmitted light these grains are deep green in colour, the immediate neighbourhood of magnetite inclusions being lighter in colour, and more translucent. No cleavage is visible. Optically it is isotropic.

A sample for analysis was obtained by pulverising portion of rock No. 16·180, treating the powder with hydrochloric acid and, afterward, with a mixture of hydrofluoric and hydrochloric acids, washing, filtering, and drying the residue. The analytical result is given in column I on a following page. This places it in the pleonaste division of the spinel group next to hercynite. Comparison with Steenstrup's results from Fiskernäs the spinel shows a lower percentage of magnesia, a condition that holds for the sapphirine and probably sillimanite also.

As already pointed out by Middlemiss (*loc. cit.*, p. 39), the geological and chemical conditions at Fiskernäs and Vizagapatam show a similarity so remarkable that sapphirine and its associates in both places seem to have been governed by similar conditions. Giesecke[1] first in 1809 discovered the Greenland occurrence which has been described geologically by Steenstrup.[2] Later Ussing[3] made a complete investigation of the mineral association.

The sapphirine-bearing schists occur as lenticular masses enclosed in gneiss or mica schist One variety of material forming these lenses consists of bronzite, sapphirine, and spinel, with accessory biotite; another of sapphirine, gedrite, monoclinic hornblende, and biotite, with smaller amounts of anorthite, cordierite, and kornerupin. In the former association sapphirine is devoid of crystal form, deep blue in

[1] Giesecke's Mineralogiske Rejse, p. 153.
[2] Meddelelser on Greenland, VII, p. 15.
[3] Zeit für., XV, pp. 598—615.

colour, and has deep blue to yellowish green pleochroic tints, while in the other it is partially idiomorphic, pale blue, and varies from bright blue to almost colourless in parallel polarised light.

The description for the first type would hold equally well for the Vizagapatam rocks, just described. In general appearance hand specimens from both regions are much alike. Ussing's second type is not so well represented among the Indian rocks, yet in specimens 16·182, 16·189 sapphirine is found sparingly in a metamorphic schist consisting of hypersthene, biotite, cordierite, sillimanite, and accessory rutile. Here it is pale blue and of weak pleochroism. It is small in amount and associated with fragments of spinel rock which appear to have been introduced in a solid state of dynamic activities. The true birthplace of sapphirine as evidenced by the Indian rock specimens is the metamorphic zone at the contact between the khondalites and spinel-bearing magmatic segregations.

It has been already shown that in chemical composition, specific gravity, and mineralogically, the metamorphic sapphirine-bearing zone is the result of intermixture of khondalite schist and segregated spinel rock, the product being rich in alumina and magnesia and iron oxides, but low in silica. Lime is practically absent in all these. Steenstrup's examination of the sapphirine rocks at Fiskernäs yielded the same conclusions. A comparison of 16·174 and 16·171 offers the fact that, though consisting of the same minerals, spinel and sapphirine are in inverse proportions, the former occupying a prominent place in 16·174, but appearing only vestigially in 16·171 as inclusions in sapphirine. In 16·172 sapphirine forms reaction rims around spinel grains. In fact, sections of 16·174, 16·172, 16·171, and 16·168 in that order would present a progressive series in which spinel is being replaced by sapphirine. The small amount of sillimanite in any of these, *e.g.*, 16·171, cannot account for all the absorbed khondalite, so the most of it has evidently been transformed mineralogically, and as the only notable quantitative evidence of such transformation is the replacement of spinel by sapphirine, the absorbed khondalite material must have been employed in the production of this alteration.

A comparison of the compositions of spinel, sapphirine, and sillimanite indicates to a marked degree the intermediate position that sapphirine bears towards the others in all its constituents, a fact which chemically substantiates the view that it is really a product of their interaction.

	I.	II.	IIIA.	IIIB.[1]
SiO_2 . .	·10	14·56	37·36	30·90
TiO_2 . .	None	...	...	...
Al_2O_3 . .	65·02	60·49	58·62	46·79
Fe_2O_3 . . } FeO . . }	22·02	7·65	2·174	2·02
CaO .	trace	...	...	...
MgO . .	13·16	17·13	·398	19·46
MnO . .	trace	...	...	...
Loss . .	...	·56	·428	1·30
TOTAL .	100·30	100·39	98·984	100·47

I.—Analysis of spinel from specimen 16·180.
II.— „ „ sapphirine from specimen 16·168.
IIIA.— „ „ sillimanite: Dana, Manual of Mineralogy.
IIIB.— „ „ Kornerupin: Steenstrup, Meddelelser on Greenland, VII, p. 20.

(*d*) Rocks free from both spinel and sapphirine.

Under this group are included rocks varying in specific gravity from 2·67 to 2·93, composed in the main of sillimanite, cordierite biotite, and hypersthene, but free, or almost free, from iron-ores, spinel and sapphirine. From this it appears as if they represent a phase in which the aluminous participant was relatively more abundant than the ferromagnesian. The minerals are fairly acid and contain about fifty per cent. of silica.

Structurally they are medium grained rocks at times slightly foliated, but usually massive. Under the microscope one observes that the sillimanite and biotite have crystallized early and are more or less idiomorphic. Between these have formed the cordierite and the hypersthene. Later pressure has bent the biotite, brought out very marked strain phenomena in the cordierite, and given the whole mass the ragged appearance characteristic of much pressed rocks.

[1] In this connection the composition of Kornerupin, the Fiskernäs equivalent of sillimanite, is cited.

Typical of this group are specimens 16·185, 16·189, 16·184, 16·169, and 15·809.

The different mineralogical constituents present some interesting features worthy of record.

Cordierite.—In many of these rocks cordierite is the most abundant constituent. It is never idiomorphic. Four types of this mineral are easily distinguished in the slides studied. In sections such as those made by Voigt and Hochgesang no pleochroism is observed, though in specially thick sections the usual blue to yellowish green colours are observed. *First type.*—The best mark for the identification of the cordierite lies in the swarms of tiny yellowish crystal inclusions which for certain vibrations of the polariser surround themselves with very beautiful pleochroic aureoles. In other instances, the inclusions are colourless, and may then be regarded as zircon. The yellowish inclusions are often well-formed crystals with straight extinction. Cross sections are rectangular, and as they are marked by the presence of two equally perfect cleavages, the mineral may be regarded as rutile. The aureoles are most brilliant when the vibration direction of the polariser coincides with one of the extinction directions of the cordierite. If the section be revolved through an angle of 90° from this position the aureoles disappear completely. *Second type.*—Here inclusions are as a rule absent, and the chief diagnostic characteristic lies in the general resemblance of the mineral to plagioclase both in twinning and polarisation tints. From this mineral, it may be distinguished by the habit of two or even three systems of twinning bands intersecting at angles of 60° and 120°. Such intersections would correspond to basal sections of this rhombic mineral with interpenetrating polysynthetic twinning with the prism (110) as twinning plane. (Pl. 1, figs. 1 and 2.) *Third type.*—Here the cordierite is free from both twinning and inclusions. It is particularly well developed in sections of much pressed rocks where it forms aggregates of grains or at times larger strained individuals resembling quartz, under similar conditions. An occasional tiny inclusion or a trace of twinning serves to demonstrate that this really is cordierite. *Fourth type.*—In this instance the cordierite appears in a form not hitherto described. It consists of an intimate intergrowth of two minerals polarising in grey tints, the two parts extinguishing separately as in the case of the micropraphic quartz felspar intergrowths. Here, however, there are no sharp edged boundaries, the whole aggregate in thin section

presenting the appearance of a vermicular intergrowth. The high power occasionally reveals polysynthetic twinning in the individual vermicular constituent minerals. This may at times be observed optically continuous with the cordierite of the second type, and then one part of the intergrowth extinguishes with one part of the twin, and the second part with the second of the twinned aggregate. In other cases small inclusions with the characteristic aureoles mark the aggregate as at least in part cordierite. (Pl. 2, fig. 1, and Pl. 3, fig. 1.)

Sillimanite.—In sections of this rock sillimanite plays a very important part. There are three fairly well-characterised varieties. The first consists of idiomorphic stout prisms usually marked by one set of parallel cleavages. Cross sections polarise in very dark grey tints or are sometimes almost isotropic. The interference figures are biaxial with very small optical angles. When slightly inclined so as to make the position of extinction quite sharp, these sections do not extinguish parallel to the one set of cleavages, a fact which seems to indicate that the mineral is not rhombic, but possibly monoclinic or triclinic. Sections in the prismatic zone polarise in brighter colours somewhat similar to those of quartz of the same thickness. Such prismatic sections may show cleavage or not according to the direction in which they are cut. The acute bisectrix is the axis of least elasticity, and the mineral is consequently positive. This type of sillimanite has been frequently described, but in the rocks here described the crystals are unusually large and well formed. *The second* variety consists of acicular aggregations of small slender crystals well individualised and easily distinguished from the *third type* which is found in fibrolitic felty intergrowths sometimes constituting a large part in the rock.

Hypersthene—is present as a chief mineral in many of the sections and is readily recognized by its strong pleochroism, sky-blue to red or red-brown. The extinction as measured on the cleavage is frequently inclined, a fact that has been noted by the writer in many so-called hypersthene rock. There can be little doubt that there is a monoclinic pyroxene with the pleochroic tints above mentioned. It is not, however, so clear as to whether there is apart from this monoclinic mineral a really rhombic pyroxene with these types of pleochroism. In many sections of the Indian charnockites, as well as in norites from Germany and Canada, the same observations have been recorded. Notwithstanding this inclined extinction on sections showing only

parallel cleavages, *viz.*, sections from the prismatic zone, it is desirable to continue to refer to this mineral as hypersthene, unless it be demonstrated that there is also a rhombic pyroxene with the properties usually assigned to hypersthene, and then it may become necessary to refer to this really common monoclinic type as clino-hypersthene.

Sometimes the hypersthene forms large individuals spangled with the well-known inclusion plates, but more frequently it consists of elliptical grains and slender crystals strung together and arranged in more or less parallel series of inclusion chains fairly well packed together. These sometimes stretch out from somewhat larger grains. This latter type appears to be the product of later changes in the rock as the strings and chains penetrate a variety of minerals and follow the boundaries between the adjoining grains. It seems to be an instance of secondary formation, resulting from the mingling of the spinel and sillimanite substances, similar in structure to the formation of secondary green hornblende by the action of plagioclase on ferro-magnesian minerals. (Pl. 3, figs. 1 and 2.) In order to show the chemical relationship between this mineral and the standard hypersthene, a chemical analysis was made on carefully separated material.

The mineral was separated in the manner described for sapphirine and a pure sample of about 8 grammes obtained. The entire quantity was used for a determination of specific gravity, a value of 3·386 being obtained. Its hardness lies slightly below that of orthoclase.

Duplicate analyses yielded the following results :—

	I.	II.	Average.
SiO_2	49·81	49·74	49·77
Al_2O_3	13·16	13·20	13·18
FeO	10·53	10·93	10·73
MnO	·37	·42	·40
CaO	trace	trace	trace
MgO	27·98	27·73	27·86
Loss	·15	·17	·16
TOTAL	102·00	102·19	102·09

These proportions, the density and optical features would place it in the bronzite division of orthorhombic pyroxenes, but the percentage of alumina is exceptionally high.

The bent and torn biotite fragments while constituting a large part of some of these rocks call for no special comment. In some of the lighter specimens such as 16·184 much pressed quartz constitutes a large part of the rock-mass. Small proportions of the opaque iron-ore and of green transparent spinel feathered by opaque inclusions complete the list of minerals present.

(*e*) Rocks free from sapphirine, but containing spinel.

In contrast to the light coloured rock dealt with under (*c*), the rocks of the present group are bluish black to brown in colour on fresh fracture with a strong tendency to rusty weathering on exposed surfaces. They usually show some trace of banding, though seldom of a well-foliated or schistose type. (Specimens 16·175, 16·176, 16·177, 16·179, 16·181, 16·183, and 16·187.)

These rocks are apparently intermediate between the rocks rich in spinel and sapphirine and those just described which are free, or nearly free, from both these minerals. The thin sections in the present suite show considerable proportion of dark minerals. The three suites of rocks seem to be related to one another—they constitute a series or a part of a series of which mention has already been made—in which the end members are ultra-basic spinel rocks and the sillimanite schists.

Mineralogically these rocks are made up of the same minerals as the light coloured rocks dealt with under (*c*), except that they are more basic and are marked by the presence of a considerable proportion of spinel. Cordierite and biotite, which are very prominent in the former class, are here quite subordinate. Sillimanite becomes relatively more abundant, and spinel makes its first appearance. From these observations it is apparent that the dark rocks are nearer to the proposed spinel prototype. Some of the slides are fairly rich in hypersthene. As this mineral usually contains about 50 per cent. silica it may be regarded as the most acid of the silicates present.

Structurally there is little to note. A greater schistosity is marked in the thin section by a parallel arrangement of the constituents, particularly of the aggregate of hypersthene grains. The spinel abounds in feathery opaque iron-ore grains which are surrounded by

clearer green areas of spinel—remote from the iron-ore the spinel contains swarms of black microscopic inclusions of iron-ore. The grains of spinel are almost invariably surrounded by a zone of colourless, limpid sillimanite, and beyond this often narrow zone lies the area occupied by the so-called hypersthene, the vermicular twinned intergrowths of cordierite and needles, and stout prisms of sillimanite. (Pl. 3, fig. 1.)

In default of a series of chemical analyses of these rocks it may be interesting to note the relationship between the classification as detailed in this paper, largely microscopical, and the grouping of the rocks as shown by their specific gravities.

	Register No.	Specific gravity.	Specific gravity of group.
1. Spinel rocks	16·174 16·180	4·05 3·78	3·91
2. Sapphirine rocks . . .	16·172 16·171 16·192 16·191 16·168 15·808	3·69 3·45 3·41 3·31 3·27 3·16	3·38
3. Spinel-bearing, but free from sapphirine.	16·179 16·175 16·181 16·183 16·177 16·176 16·187	3·40 3·34 3·30 3·17 3·14 2·94 2·86	3·16
4. Free from sapphirine and spinel .	16·185 16·189 16·184 16·169 15·809	2·93 2·81 2·74 2·71 2·67	2·76
5. Rocks with traces of sapphirine and spinel.	16·186 16·190 16·182 16·173	3·31 3·31 3·05 3·31	3·25

III.—CONCLUSIONS.

1. The occurrence of the Indian sapphirine rocks is practically identical with that of Fiskernäs in Greenland. They appear to be the result of mingling and subsequent metamorphism of ultra-basic igneous borders and very aluminous para-schists rich in sillimanite.

2. The cordierite present in the thin sections appears in a number of types, some of which appear to be new to petrography.

3. A member of the pyroxene family of minerals possessing the pleochroism of hypersthene, but, with oblique extinction, is present in a number of the rocks examined. If there be really a rhombic pyroxene with the characteristics usually ascribed to it, then this Vizagapatam pyroxene may require a distinct name, and the writers suggest that it be then known as clino-hypersthene.

IV.—EXPLANATION OF MICROPHOTOGRAPHS.

PLATE 1, FIG. 1.—Cordierite containing zircon crystals surrounded by pleochroic aureoles. Polariser only. Section from specimen 16·186. (× 23 diameters.)

PLATE 1, FIG. 2.—Same section as No. 1, showing well-twinned cordierite. Nicols crossed. (× 23 diameters.)

PLATE 2, FIG. 1.—Vermicular intergrowth of cordierite. Section from specimen 16·183. Nicols crossed. (× 23 diameters.)

PLATE 2, FIG. 2.—Spinel rocks 16·180, showing inclusions of magnetite in spinel with clear zones around these iron-ore grains. Ordinary light. (× 40 diameters.)

PLATE 3, FIG. 1.— Spinel grains (black) surrounded by clear zone of cordierite beyond which is a narrow zone of hypersthene. The main light coloured part of the section is vermicular cordierite, while the particles of intermediate tint are hypersthene. Ordinary light. Specimen 16·181. (× 40 diameters.)

PLATE 3, FIG. 2.—Spinel (black) surrounded by sapphirine intermediate in tint, beyond which is hypersthene in still lighter tints. Specimen 16·172. Ordinary light. (× 40 diameters.)

NEPHELINE SYENITES FROM THE HILL TRACTS OF VIZAGAPATAM DISTRICT, MADRAS PRESIDENCY. BY T. L. WALKER, M.A., PH.D., *University of Toronto.*

THROUGH the kindness of the Director of the Geological Survey of India the series of rocks here described was sent me for laboratory study. They were collected during the field season 1901-02 by Mr. C. S. Middlemiss, Superintendent of the Geological Survey of India, while making a survey of that region.

The field relationships of these rocks appear to be those of igneous instrusions occurring along with other gneissoid igneous types (charnockite and biotite gneissoid granite) forming part of the great boss extending from the Godavari to the Mahanadi, constituting for two hundred and fifty miles the northern portion of the Eastern Ghauts. This giant eruptive is overlaid in part by metamorphosed sediments, principally by khondalite, and to a less extent by laterite. The specimens studied were collected a short distance north-east of the town of Koraput.

These rocks are readily recognized as nepheline-bearing, even macroscopically, by the depressions on the weather surface, due to the leaching out of the somewhat soluble nepheline, and on freshly broken surfaces by the oily lustred, light coloured grains of this mineral.

The specimens forwarded to me are of two main types, the first light in colour, somewhat banded and streaked by dark drawn out bands and patches of biotite and hornblende (specimens 16·164); the second composed of large porphyritic crystals of nepheline enclosed in a mass of mylonitic material, which has apparently been formed by the application of considerable pressure to a very coarse pegmatitic variety of the rock containing phenocrysts of nepheline as large as walnuts (specimens 16·164). Both are probably of the same massif though the pressure which lent to the first only an indistinct gneissoid structure without the least sign of granulation caused in the second cataclastic structures which are readily apparent.

The first mentioned type when examined under the microscope is seen to belong to that class of nepheline syenites containing relatively

more biotite than hornblende, approaching in this regard the typical miaskites of the Urals, from which it would be impossible to distinguish it without the aid of the microscope. Greenish-brown hornblende, brown biotite, and magnetite grains more or less idiomorphic make up only a very small fraction of the rock-mass. Anhedra of nepheline and large irregularly rounded grains of felspar constitute the major portion of the rock.

As seen under the microscope, the most interesting constituent is the felspar. No twinning is to be observed. The irregular masses of this mineral when examined with crossed nicols break up into two parts—into a series of similarly oriented lenses included in a groundmass which for the rest of the grain possesses a uniform orientation. This suggests the micro-perthitic structure, though no twinning is observed in any of the included lenses. That it is really a complex of the ordinary perthitic type despite the absence of twinning is proved from the accompanying analysis. In the matter of felspars our Indian miaskite differs in microscopic appearance from the type from the Urals in which both plagioclase and orthoclase are present as distinct individuals, though never in the form of perthitic intergrowths.

With a view to determining the approximate proportion of nepheline present in the rock a small portion of the prepared powder of 16·164 was treated with warm dilute hodrochloric acid. In this way the nepheline and calcite, and possibly in part the very small quantity of biotite, were decomposed. The soluble portion was filtered off and the residue treated with caustic potash. The residue after this second treatment when dried and weighed was found to constitute only 61·16 per cent. of the original powder. The loss in dissolved minerals—almost entirely nepheline—would therefore represent 38·84 per cent. corresponding to a nepheline content of about 37 per cent.

Calcite is a somewhat unusual constituent for a decidedly igneous rock as fresh as the specimens in question. It forms cleavable well-twinned anhedra, which, judging from the determined amount of carbonic acid, 55 per cent., makes up about one per cent. of the whole rock. It can hardly be regarded as other than an original constituent of the rock-mass. Calcite occurring in the nepheline syenites of Sivamalai, South India, has been similarly regarded by T. H. Holland[1] as an original constituent of the igneous rock.

[1] Holland. The Sivamalai series of Elæolite-syenites and Corundum-syenites, *Mem. Geol. Surv. Ind.*, XXX, 1901, pp. 197 and 214.

The result of the analysis of 16·164 is recorded in I: miaskite from the Urals is given in II:[1] in III is presented an analysis of a closely related rock from Sivamalai.[2]

	I.	II.	III.
SiO_2 . . .	52·60	56·26	55·68
Al_2O_3 . . .	26·60	23·59	23·81
Fe_2O_3 . . .	·91	·85	4·84
FeO . . .	2·21	2·61	
MgO . . .	·51	·27	·65
CaO . . .	1·89	·54	1·69
Na_2O . . .	7·06	7·77	9·23
K_2O . . .	6·94	5·72	5·16
CO_2 . . .	·55	1·37	...
TiO_2 . . .	...	·47	...
MnO . . .	...	·09	...
Graphite . .	...	...	·58
H_2O . . .	·61	·37	·34
TOTAL .	99 88	99·91	101·98
S. G. . . .	2·65	...	2·593

The position of the miaskite according to the system of the authors of a "Quantitative Classification of Igneous Rocks"[3] is a peculiar one. By the method of arrangement in question rocks of similar chemical composition are brought together, without regard to the structure. In a general way the molecular proportion of the ferro-magnesian minerals is less than one-seventh of that of the light

[1] Karpinsky, Guide, VII, Cong., G., Inter., V, p. 22, 1897.
[2] *Mem. Geol. Surv. Ind.*, XXX, p. 181.
[3] Cross, Iddings, Pirrson and Washington. Quantitative Classification of Igneous Rocks.

coloured constituents. This brings it into the large class, Persalane. The richness of the rock in alumina refers us to sub-class II. In short, such considerations as these, based entirely on the results of the chemical analysis, places the Vizagapatam miaskite as follows:—

Class I, Persalane.
Sub-class II.
Order 7.
Rang 2.
Sub-rang 3.

It would not be surprising if this miaskite should turn out later on more thorough field study to be associated with rocks bearing corundum. Judging from the very high proportion of alumina as well as from the known mineralogical and petrological associations of similar rocks in the south of India, in central Ontario, and in Montana, we are in a measure warranted in anticipating such occurrences of valuable corundum deposits.

Associated with these typical light coloured nepheline rocks occur darker border types suggesting in hand specimens gabbros or diorites 16·164. As seen under the microscope, the rock is composed largely of a yellow-brown strongly pleochroic hornblende, and to a less degree of plagioclase, biotite, and magnetite. After corroding with acid and staining, one observes that numerous small rounded grains, which polarise in dark grey tints, have been attacked by the acid and hold the stain. These small grains are therefore nepheline and the rock becomes a theralite in which the dark minerals are hornblende and biotite to the exclusion of pyroxene. Rocks of this type occur in various parts of the world, usually in association with nepheline syenites, forming basic border segregations. The high specific gravity, 3·08, corresponds to the general basic mineralogical composition.

THE STRATIGRAPHICAL POSITION OF THE GANGAMOPTERIS BEDS OF KASHMIR. BY H. H. HAYDEN, B.A., F.G.S., *Superintendent, Geological Survey of India.* (With Plates 4—9.)

DURING the past summer advantage was taken of the opportunity, afforded by a visit to Kashmir, to spend a few days at Khunmu with a view to ascertaining the true stratigraphical position of the plant-bearing beds exposed on the Risin spur at the mouth of the Nagowan ravine.

Fossils were first found in these beds by Dr. Noetling in 1902.[1] His collections, described by Professor A. C. Seward and Dr. A. Smith Woodward,[2] comprised species of *Gangamopteris*, *Amblypterus*, and *Archegosaurus;* all the species were new, but the fishes and the Labyrinthodont proved to have close affinities with lower Permian and Coal-measure forms. The importance of this evidence of the Palæozoic age of *Gangamopteris* in India had already been pointed out by Mr. Holland,[3] but it still remained to ascertain the precise relationship of these plant-bearing beds to the fossiliferous marine sediments occurring in the same area. Unfortunately the outcrop from which Dr. Noetling's specimens were collected occurs on a small spur jutting out into the alluvial plain,[4] and the uppermost beds, in which most of the fossils were found, dip under recent fan deposits of unknown, but probably considerable, thickness, the nearest outcrop of the fossiliferous Zewan beds being over three-quarters of a mile distant.

Although it was assumed that the true stratigraphical position of the Gangamopteris beds was below that of the Zewan beds, this was not definitely ascertained by Dr. Noetling, and a subsequent visit was paid to the locality by Mr. R. D. Oldham, who not only re-examined the Risin spur, but also searched all the known fossiliferous

[1] T. H. Holland: *Gen. Rep. Geol. Surv. Ind., 1902-03,* p. 23 (1903).
[2] *Pal. Ind., New Ser.,* Vol. II, Mem. 2 (1905)
[3] *Op. cit.,* p. 22; also *Rec. Geol. Surv. Ind.,* XXXII, 153 (1905).
[4] F. Noetling: *Centralblatt für Min., Geol. und Pal.,* p. 129 (1904).

localities in the Vihi plain.[1] On the Zewan section, he found a band of black shale, with carbonised plant remains, which, in its method of weathering, resembles the matrix of the Gangamopteris beds of Risin. Mr. Oldham, however, met with no determinable fossils at this horizon and was therefore unable to identify it directly with the Gangamopteris beds. It was consequently considered advisable that advantage should be taken of the first opportunity to re-visit the Khunmu area and make a further attempt to find the Gangamopteris horizon on a continuous section.

The Risin outcrop.

From the plan published by Dr. Noetling[2] it would appear that the plant beds occur as an isolated exposure between an outcrop of trap on the one hand and of the Zewan beds on the other, and separated from both by recent talus slopes and fan deposits: this, however, was found not to be an accurate representation of the area, and a plane-table sketch-map was therefore prepared, on a scale of 400 feet to the inch: a reduction of this is published on Pl. 4, fig. 1. Dr. Noetling's conclusions as to order of succession of the beds were based chiefly on the supposed concordance of dip in all the outcrops; our observations on this point, however, as well as on that of the relative positions of the outcrops, are mutually conflicting, and since reference will be made to the map from time to time, it has been considered advisable to reproduce also Dr. Noetling's plan (see Pl. 4, fig. 3). From the sketch-map it will be seen that the Gangamopteris beds form the end of a spur, lying at about four-fifths of a mile to the west-north-west of Khunmu and running down from a high hill composed of trap, and dip under the recent fan of the Nagowan stream (see also Pls. 5 and 6). The crest of this small spur constitutes the line of junction between the Gangamopteris series and the underlying trap: the junction is perfectly clear and the passage from the one series into the other, although rapid, is not abrupt.

The uppermost of the trap bands is a grey compact rock containing fairly numerous amygdules of (?) palagonite and chalcedony. It is much altered, but can still be seen to have had a glassy matrix and may have been an andesite: this cannot be determined without a much more detailed examination than I was able to make during the few days of my stay.

[1] R. D. Oldham: *Rec. Geol. Surv. Ind.*, XXXI, 5 (1904)
[2] *Op. cit.*, p. 133, fig. 2.

The trap is overlain by a bed about three feet thick, of green, shaly material; above this is a thin band of shale (8 inches) overlain by a bed (about 3′ 6″) composed of dark, almost black, crystalline limestone and black chert in intimate association: over these are carbonaceous shales (15—20′)—with an occasional thin band of black crystalline limestone—followed by a second bed of limestone and chert (10 feet), overlain by carbonaceous shale.

The two bands of carbonaceous shale correspond to beds 9 and 11, respectively, in the section given by Dr. Noetling[1] and it is in these that the fossils were found. The lower band appears to contain only *Gangamopteris* and that only in the uppermost layers, and it is the upper bed which has yielded the greater part of the rich collections made by Dr. Noetling, and more recently augmented by Mr. Oldham and myself. The greater productiveness of the upper band may be merely apparent, since the dip of the bed corresponds approximately with the slope of the hill-side and the outcrop is therefore very extensive (Pl. 6).

It will be seen from the sketch-map that on the south and east the exposure is bounded by recent deposits, whereas on the west and north it is in contact with the underlying trap: hence no younger beds are exposed in this locality.[2]

Section in Guryul ravine.

The nearest point at which sedimentary rocks are again found overlying the trap is in the Guryul ravine, the mouth of which lies at a little over a mile to N. 15° W. of Khunmu and 1,200 yards N. E. by N. of the Risin spur.[3] At the mouth of the ravine the trap is seen on the right-hand side of the stream and limestones with *Athyris*, *Productus*, etc., on the left: the interval between is covered with recent stream deposits and it is necessary to go some little

[1] *Op. cit.*, pp. 130, 131. His description of the lower band as "erdiger Kalkschiefer" does not accord with my observations; the matrix of the specimens of *Gangamopteris* that I obtained from this band is a black carbonaceous shale, quite free from calcareous matter. There may, however, be local variation.

[2] The section given by Dr. Noetling in the paper already referred to must be regarded as purely diagrammatic; the beds (2—11) are shown as dipping to the north, whereas their actual dip is E. S. E. at one end of the exposure and S. E. at the other.

[3] This ravine is readily recognised by the presence of two large chenar trees at its mouth: see Lydekker, *Mem. Geol. Surv. Ind.*, XXII, 131, 132 (1883), and Godwin-Austen, *Quart. Journ. Geol. Soc.*, XXII, 33 (1866).

distance up the gorge before an uninterrupted section is found. At about 300 yards above the mouth, a conspicuous spur runs down between the two main branches of the stream, and in the more easterly of these tributaries an uninterrupted section is found from the trap through cherts to the Gangamopteris series and the Zewan stage up to beds of undoubted Triassic age.

The uppermost trap band is a somewhat amygdaloidal rock, very similar to that of the Risin spur, but the overlying beds appear at first sight to differ markedly on the two sections. It has already been pointed out by Mr. Oldham that the beds in the Guryul ravine have suffered from crushing and faulting, and it is not easy to find a section free from disturbance, but at the point already defined the sequence appears to be a normal one; it is as follows:—

Zewan beds .	7. Shale and limestone with *Bryozoa* and brachiopods.
Gangamopteris series.	6. Chert with thin bands of silky grey shale.
	5. French-grey shale and dark carbonaceous shale with intensely hard grey siliceous band.
	4. Chert, chiefly dark-blue and black, with pale, sometimes white, patches.
	3. Silky shale,—crushed, almost a phyllite.
	2. White chalcedony (novaculite).
	1. Amygdaloidal trap.

Comparison of Risin and Guryul sections.

At first sight there would appear to be little or no resemblance between this section and that of the Risin spur, but a closer examination of the individual beds soon shows that the sections have two peculiar and characteristic elements in common: these are the chert bands and the carbonaceous shale. The latter rock is remarkable for the fact that on fresh fracture it is intensely black with numerous black shining specks and fragments of vegetable matter, but on exposure it bleaches to a grey, pale buff, or almost white rock; in the Guryul ravine, however, this band is only a few inches thick, whereas on the Risin spur the thickness is very considerable.

Chert bands.

The cherts, which are most conspicuous on both sections, are also very characteristic rocks: at Risin they are almost invariably black and are intimately associated with dark crystalline limestone, the two rocks alternating and passing into one another not only vertically, but also along the strike; bands and lenticular patches of the limestone run through

the chert, the one rock appearing in the field to pass insensibly into the other. In the Guryul ravine, on the other hand, limestone is practically absent; a few patches of very impure calcareous material in bed No. 4 being the only apparent representatives of the well-defined limestones of Risin. Here, however, chert is very much more abundant and more variable both in colour and in texture, ranging from a black velvety rock to a creamy white variety, exactly like "Arkansas stone,"[1] the typical form of novaculite.

Fossil plants on Guryul section.

The presence of cherts in both sections first led to a careful search for *Gangamopteris* in the Guryul ravine, but it was only after an exhaustive examination of every layer on the section described above that a frond was at last found in the intensely hard siliceous band associated with the carbonaceous shales (bed No. 5); a few more fragmentary specimens were obtained from the same layer, but all are very poorly preserved and the evidence seemed hardly conclusive.

Zewan section.

A visit to the Zewan section (Pl. 7), near Panduchak, however, removed all doubts and completely established the position of the Gangamopteris horizon. This section is already familiar from the work of Godwin-Austen,[2] Verchere,[3] and, recently, of Mr. Oldham. Here a complete sequence is found ranging from the trap up to the shales and limestones with marine fossils, named by Godwin-Austen the "Zewan beds." The beds dip at high angles (50°—60°) to east-south-east. Near the base of the section Mr. Oldham found a bed of carbonaceous shale exactly like that in which *Gangamopteris* occurs on the Risin spur. I was fortunate enough to be able to confirm the identity of these two beds, since at Zewan I found specimens of *Gangamopteris* similar to those of Risin. Above the carbonaceous shales there appears to be a perfectly conformable sequence up to the fossiliferous Zewan beds.

Along the crest of the ridge, the trap is immediately overlain by a white chalcedonic rock, like that of the basal bed in the Guryul ravine and identical with novaculite: from this a section (Pl. 4, fig. 2)

[1] I am indebted to Mr. T. R. Blyth, Assistant Curator, Geological Survey of India, for drawing my attention to the remarkable resemblance between the two rocks.

[2] *Quart. Journ. Geol. Soc.*, XXII, 33 (1866).

[3] *Journ. As. Soc. Bengal*, XXXV, No. 2, 129 (1867).

was measured up to the shales with marine fossils (Zewan stage): it is as follows:—

Zewan beds.	23. Shale with *Protoretepora ampla, Lyttonia* and brachiopods	...
	22. Cherty band with *Productus cora* d'Orb.	4 ft.
Gangamopteris series.	20. Dark grit	3 ins.
	19. Shale, calcareous and earthy	4 ft.
	18. White and green chert	1 „
	17. Shaly siliceous grit	4 „
	16. Chert and fine-grained quartzite	50 „
	15. Shale in 1 ft.—3 ft. beds, with thin limestone bands	18 „
	14. Thin-bedded limestone, with some shale at the base	15 „
	13. Hard siliceous shale, slightly carbonaceous at the top and containing a few fragments of plants	12 „
	12. Carbonaceous shale	4 „
	11. Shale and thin-bedded limestone	25 „
	10. Shale like 8, with thin (2"—3") pebble band at base	4 „
	9. Somewhat concretionary limestone, with occasional shale bands	2 „
	8. Shaly pebble bed: pebbles large (up to 5" in diameter) in lower part and small in upper	3 „
	7. Flaggy siliceous-bed with bands of small pebbles	1 „
	6. Siliceous shale or chert	10 „
	5. Limestone	4 „
	4. Siliceous shale or chert	7 „
	3. Carbonaceous shale with *Gangamopteris*	3 „
	2. Siliceous shale	20 „
	1. White novaculite	25—30 „ (variable).

Gangamopteris at Zewan.

The most important feature of the section is naturally the presence of *Gangamopteris* in the carbonaceous shales. The fossils are extremely rare and the few found were only obtained after prolonged search: they are best seen on the weathered surface of the shale. I found no traces of either *Amblypterus* or *Archegosaurus*, but the few hours at my disposal were quite insufficient for a thorough exploration of the bed. Circumstances unfortunately precluded a longer stay and it was impossible to do more than measure and examine the rest of the section in a most cursory manner, but a few observations were made which seem to throw some light on the relationship of the volcanic beds to the overlying rocks.

Novaculite.

The first of these relates to the basal bed, the novaculite,[1] as seen on the crest of the spur. This rock has been described variously as a compact quartzite (Godwin-Austen) and a bed of quartz (Oldham), but in both macroscopic and microscopic characters it agrees entirely with a specimen of "Arkansas stone" included among the collections in the Geological Museum in Calcutta. On the Zewan section it forms a thick bed on the crest of the spur and is immediately overlain by siliceous shale, the chert and limestone which is seen at the base of the Risin section being apparently absent. If, however, the novaculite bed is followed towards the west, it is found to thin out rather rapidly to a thickness of only six or seven feet and then to dwindle away to nothing. As the novaculite thins out, its place is taken by crystalline limestone and chert, and at the end of the outcrop nearest to Panduchak the sequence is similar to that at Risin. The presence of the novaculite on some sections and its absence from others was drawn attention to by Mr. Oldham and was possibly one of the causes that led him to assume that the junction between the trap and the overlying beds was an unconformable one; others were the abrupt cessation of volcanic rocks at one particular horizon and the remarkable variation in the respective sections.

Origin of the cherts and novaculites.

The capricious distribution of the novaculite is at first sight puzzling, but a study of the sections shows that where it is present the lowest limestones are absent or only imperfectly represented. The section at Zewan includes both rocks, the novaculite being at one end of the outcrop and the limestone at the other, while the interval between the two is occupied by both rocks but in reduced thickness; it is impossible to resist the conclusion that the novaculite has originated in the metasomatic replacement of the limestone by silica. Such an origin was suggested some years ago by Mr. F. Rutley for the Arkansas novaculite,[2] and his theory is entirely borne out by the Kashmir rocks.

Under the microscope, their history can be followed with wonderful clearness, and a perfect passage traced from an almost pure limestone into a black chert and thence into typical novaculite.

The original condition of the rock was an oolitic limestone (see Pl. 8, fig. 1); this subsequently became crystalline on a coarse scale,

[1] If this rock can be found free from joints, it should be valuable as a whet-stone.
[2] *Quart. Journ. Geol. Soc.*, Vol. L, 377 (1894).

for many adjacent calcite grains as well as the intervening ground-mass show the same orientation over very considerable areas. Under the microscope, this is clearly seen in the simultaneous extinction of large areas and in the extension of the twin-lamellæ of the calcite from grain to grain across the ground-mass (fig. 2), while in the hand specimen the effect is a very striking " lustre-mottling."

The next stage was the gradual replacement of the calcite by chalcedonic silica to form a black chert; the ground-mass was first attacked, and the process can be traced in every stage through a rock composed of grains of calcite imbedded in a matrix of chalcedony (Pl. 9, fig. 3) to the final chert composed of oolitic grains of silica in a matrix of the same material (Pl. 8, figs. 3 and 4).

The dark colour of the limestone and of the resultant chert appears to be chiefly due to carbonaceous matter, but also to the presence of some fine mud and a little manganese oxide.[1]

These dark materials originally either occupied the centre of the grains of oolite or were deposited in rings during their formation: both conditions can be seen in the limestone. When crystallisation set in, either the original conditions survived or in some cases the dirt was exuded towards the outer surface and is now seen as a dark ring round the grains or is occasionally noticed along the cleavage cracks of the calcite.

The evidence furnished by the microscope leaves no doubt as to the inorganic origin of these cherts, for they not only retain perfectly the oolitic structure of the original limestone, but every stage in the replacement of the calcite by silica can be traced. Nor is the silicification confined to the limestones, but has extended to the associated shales and sandstones, and in the Guryul section the carbonaceous shale with plant remains has been converted into a hard hornstone breaking with conchoidal fracture. At the same time the negative evidence implied in the absence of recognisable sponge spicules or other siliceous organisms further supports the above view. The mode of origin of the oolitic grains is uncertain, and may have been either organic or inorganic, but certain structures visible under the microscope are suggestive of the tests of foraminifera, such as *Endothyra*, while several plant fragments can be clearly recognised as nuclei of the grains.

[1] The limestone contains alumina and gives a decided reaction for manganese.

Silicification due to solfataric action.

As will be seen below (p. 36), there is no reason[1] for supposing that there was any great time interval between the occurrence of the last lava-flow and the deposition of the carbonaceous limestones; the cherts and novaculites may consequently be regarded as products of the final or solfataric phase of the volcanic activity. The novaculite differs from the chert chiefly in colour and in the almost complete obliteration of the oolitic structure, but even here intermediate stages can be found, for some specimens have a distinct granular structure and contain occasional patches and strings of dirt; as a rule, however, the rock is bluish, greenish, or creamy white, and free from the carbonaceous matter to which the chert and limestone owe their colour; and it may be regarded as a bleached chert, which might have been produced by the action of heat on the carbonaceous rock, having thus been formed in the immediate neighbourhood of fissures in the underlying trap. Solfataric action would not only suffice to explain the silicification of the limestones, but would also account for the local substitution of novaculite for chert.

The period during which this silicification occurred can be defined with considerable nicety, for it has nowhere been found to extend as high as the beds with *Protoretepora ampla*, which occur near the base of the fossiliferous Zewan beds (bed 7 in the Guryul ravine and bed 23 on the Zewan section). It must, therefore, have taken place after the solidification of the last trap-flow and before the deposition of the beds with *Protoretepora ampla*: that it began at an early part of this period would appear from the fact that pebbles of a chert exactly like that of the main band at the base of the series occur in a pebble-bed (bed 8) low down in the section at Zewan; if the two rocks be the same, the chert must have been formed and locally denuded at an early stage. Not only cherts, however, but silicified shales and sandstones occur again higher up in the same section (bed 16), while in the Guryul ravine chert bands occur throughout the whole section between the trap and the Zewan beds; it is evident, therefore, that silicification occurred more or less throughout the whole period during which the beds of the Ganmopteris series were beingdeposited. This lends further support to the view that it represents the solfataric stage of this volcanic period.

Local variation of Gangamopteris series and Zewan beds.

Much of the variation to which attention has been drawn by Mr. Oldham can thus be explained by local alteration of the component beds on the respective sections, but this does not account for such evident

difference of character of the original sediments as is readily apparent from a comparison of a section such as that of Zewan with those of Mandakpal and Rechpura on the eastern side of the Vihi plain. At Zewan the beds between the trap and the base of the Zewan beds are over 200 feet thick and include littoral deposits (pebble-beds, sands, etc.), whereas at Mandakpal they consist of a considerable thickness of dark ferruginous shale, capped by a band (5 feet thick) of greenish and bluish chalcedony. At Rechpura, according to Mr. Oldham, the lowest limestones of the Zewan stage lie directly on the volcanic beds. Although this variation does not necessarily imply unconformity, since the shore deposits of Zewan might well be represented by shale and limestone at a locality ten miles distant, yet it is not unnatural to expect that local disturbances occurred during a period of such marked volcanic activity; but if any unconformity does exist, it does not necessarily involve any great time interval: this has already been pointed out by Mr. Oldham, and since none of the usual direct evidences of unconformity—such as discordance, erosion of the trap, the presence of conglomerates, etc.—are found on the section at Zewan, there is no reason to suppose that there was any serious interruption of continuity between the outpouring of the last lava-flow and the deposition of the Gangamopteris series.

With regard to the question of a possible unconformity above the Gangamopteris beds, I have seen only a few of the many sections to be found in and around the Vihi plain and am consequently not in a position to deal with this adequately. So far as I could see there is no evidence of any break between the Gangamopteris beds and the Zewan stage either at Zewan or in the Guryul ravine. On the former section the presence of pebble-beds and carbonaceous shales with remains of land plants is suggestive of either coastal or estuarine conditions, and the pebble-beds may undoubtedly be taken to indicate a certain amount of contemporaneous erosion due to local oscillations of the coast-line.

In the Guryul ravine the Gangamopteris series is thinner than at Zewan and more completely silicified, but the carbonaceous shales (bed 5, *supra*, p. 26) are exactly like those of Risin and Zewan, and furthermore contain fragments of plants, which, though very badly preserved, are, I think, referable to *Gangamopteris*. If, therefore, we find such marked lithological variation in the space of about three miles—the distance of the Guryul ravine from Zewan—we should

naturally expect even greater variation at more distant localities, such as Mandakpal and Rechpura, which were probably some way from the coast-line as defined by the Gangamopteris beds, and it would not be surprising to find the shallow-water deposits of the one area represented by limestones in the other.

At Zewan the Gangamopteris series is overlain first by a thin band of somewhat siliceous limestone containing *Productus cora* d'Orb.; above this is a considerable thickness of black shale full of beautiful specimens of *Bryozoa*, the most conspicuous of which is *Protoretepora ampla* Lonsd.; above this again is a limestone containing a variety of fossils, chiefly brachiopods. Wherever beds of the Zewan stage were seen by me, the horizon of *Protoretepora ampla* was always recognised immediately by the excellence and profusion of this characteristic fossil. At Zewan it is apparently restricted to shale; in the Guryul ravine it is found partly in a thin bed of shale and partly in limestone; on a ridge to the south-west of Mandakpal, it is found chiefly in shale, whereas to the east-south-east of the same village the rock in which it occurs is almost exclusively a limestone; thus we have the same horizon represented in one place by shale, in another by limestone, and in a third partly by both; this is of course only what might be expected, and is, I think, sufficient to justify us in considering the case for unconformity above the Gangamopteris series not fully established. We thus have evidence that the Gangamopteris series is older, but, if we assume that there is no unconformity, only slightly older, than the Zewan stage.

The Zewan stage.

The Zewan stage (*sensu stricto*), as defined by Godwin-Austen, includes only the fossiliferous shales and limestones capping the section at Zewan, but has generally been taken to comprise the fossiliferous series with *Bryozoa* and brachiopods as seen in part at Zewan, and more completely in the Guryul ravine and at other localities around the Vihi plain,[1] and so to include all the beds between the Gangamopteris series and the lower Trias. The presence of the latter stage had not been detected at Khunmu, where it was supposed by Dr. Noetling that the upper Trias was faulted against the Zewan beds. This view is represented in the diagram published by Dr. Noetling in his paper already referred to.[2]

[1] R. Lydekker: *Mem. Geol. Surv. Ind.*, XXII, 132 (1883).
[2] *Op. cit.*, p. 130, fig. 1.

I was unfortunately unable to devote any time to this section, but traversed it rapidly at two or three points on the left side of the Guryul ravine. All the beds above the Gangamopteris series are shales and limestones, and consist roughly of limestone with subordinate shales below, followed by shale with subordinate limestones, and these again, capped by a thick series of limestone forming steep cliffs. The lowest group of beds comprises the horizon of *Protoretepora ampla*, followed by several brachiopod-bearing horizons, characterised chiefly by the genera *Athyris* and *Productus*: the next group consists chiefly of shale below with alternating beds of shale and limestone (in beds of from 6 inches to 1 foot in thickness) above. This second group is very well exposed on the small spur ending in the cliff over-hanging the chenar trees at the mouth of the Guryul ravine where it forms the saddle running from the top of the cliff to the foot of the next limestone cliff to the east (Pl. 6). Further up the ravine these lower beds, which are largely composed of shale, contain fossils, collected in small patches which evidently represent hollows in the old sea-floor; the fossils are chiefly *Marginifera himalayensis* Diener and are characteristic of the Productus shales in other parts of the Himalaya. At about 10 feet above this horizon is a band of dark shale weathering white and not unlike the carbonaceous shales of the Gangamopteris series: it does not, however, contain plant remains, but yielded a few specimens of *Pseudomonotis* sp. cf. *Griesbachi* Bittner. Immediately above this is a thin band of very hard limestone with species of *Danubites*, *Flemingites*, and *Bellerophon*. This is followed by rapidly alternating beds of similar hard limestone and shale: the whole sequence bears a striking lithological resemblance to the lower Trias of Spiti and the fossils at the base leave no doubt as to its identity. The third group, which is composed of hard limestone in beds of about 2 feet thick, and forms a conspicuous line of cliffs on the left side of the valley, probably represents the nodular limestone and the muschelkalk of Spiti, but I had no time to search for fossils which appear to be very rare.

Section in Guryul ravine.

Productus shales.

Lower Trias of Guryul.

The above is only a very broad classification of the beds above the Gangamopteris series, but it is sufficient to prove the presence in the Guryul ravine of at least three well-marked stages,—a calcareous series below, with *Bryozoa* near the base and *Athyris* above, a (mainly

shaly) series in the middle, with *Marginifera himalayensis*, and an alternating series of shale and thin-bedded limestone containing fossils of lower Triassic age.

Mandakpal: Productus shales.

Turning now to Mandakpal at the other side of the Vihi plain, the sequence exposed on the ridge to the east-south-east of the village, from the base of the Zewan stage upwards, is very similar, with the exception that all the beds are rather more calcareous. In the middle shaly series two highly fossiliferous bands are well exposed; the lower is a continuous bed, several inches thick and is almost entirely made up of *Marginifera himalayensis* Diener and other brachiopods. A little higher in the section, a calcareous bed, about six inches thick, is equally rich in specimens of *Spirifer rajah* Salter and other species of *Spirifer*.[1] There can, I think, be no doubt that these shales, with *Marginifera* and *Spirifer* at Mandakpal and *Marginifera* in the Guryul ravine, represent the Productus shales of Spiti and the rest of the Himalaya, differing from them only in being locally rather more calcareous; they are, however, often micaceous and are then exactly like the Productus shales of Spiti.

Age of Zewan stage.

Some years ago, before I had had an opportunity of seeing the Zewan beds, I suggested that they were probably the equivalent of the Fenestella shales of Spiti;[2] in this Dr. Diener agreed with me,[3] and I am now convinced that our view was on the whole correct, although it will require some modification if we include in the term Zewan stage all the beds between the Gangamopteris series and the lower Trias: in that case the Fenestella shales will be represented by the lower beds with *Protoretepora ampla* and other *Bryozoa*, and the Athyris limestones of Vihi may be the equivalent of the calcareous sandstone of Spiti.

Age of the Gangamopteris series.

It has now been definitely ascertained that the Gangamopteris beds overlie the trap and underlie the Zewan beds: their age consequently depends on that adopted for the latter stage. This is usually regarded as upper Carboniferous, but it has now been shown that the Zewan beds include the Productus shales, which are admittedly of

[1] These are evidently the bands referred to by Lydekker: *op. cit.*, p. 134.
[2] *Gen. Rep. Geol. Surv. Ind., 1899-1900*, p. 189.
[3] C. Diener: *Pal. Ind.*, Ser., XV, I, pt. 2, p. 199.

Permian age: if the term "Zewan stage" is to be retained, it should be rigidly restricted to the horizons exposed at Zewan and originally so named by Godwin-Austen; the lower of these includes beds 22 and 23 (*supra*, p. 28) of which bed 23 is almost certainly the equivalent of the Fenestella shales of Spiti, and consequently of upper Carboniferous age. Bed 22 is only of inconsiderable thickness, but contains immense numbers of *Productus cora* d'Orb. and may thus be homotaxial with the Cora horizon of the Ural and Timan mountains. Such a correlation is borne out by the fact that the overlying bed (23) contains *Lyttonia* and may therefore be homotaxial with the *Lyttonia*-bearing beds of Loping in China which have been referred by Professor Tschernyschew to the Schwagerina horizon of the Urals.[1] This, however, is merely offered as a tentative suggestion, since no close or systematic study has ever been made of the upper Palæozoic horizons of Kashmir in the light of recent stratigraphical discoveries; it is highly desirable that this should be done since the results will certainly help to elucidate the relationship of the Carboniferous deposits of the Central Himalaya and the Salt Range to those of Eastern Europe. All we can say at present is that the Gangamopteris beds are not younger than upper Carboniferous and may belong to the base of that sub-division or even to the middle Carboniferous. The lower limit of age can only be decided by determining the age of the trap. This will be a matter of great difficulty, but some light will probably be thrown on the question by a section recently observed at Imselwara (or Ambersilwara) near Harwan, in the hills to the N.N.E. of Baramula. Here I found a series of limestones, probably between two and three hundred feet thick, interbedded with the trap.[2] Fossils are numerous, but very poorly preserved; they include species of *Spirifer*, corals, and crinoids. The limestones are quite unlike those of the Zewan stage and are probably much older: I was unfortunately unable to stop to examine them, but it is probable that further search would result in the discovery of determinable fossils and go far towards establishing the age of the trap.

Imselwara limestone.

[1] Th. Tschernyschew: Die ober-carbonischen Brachiopoden des Ural und des Timan. *Mem. Com. Geol.*, XVI, No. 2, St. Petersburg (1902), p. 729. (A translation of parts of this paper has been published in *Rec. Geol Surv. Ind.*, XXXI, pt. 3.)

[2] The cave containing pleistocene fossils, and recently discovered by Messrs. Radcliffe and Campbell, is in this limestone: see *Indian Forester*, Vol. XXXII, No. 6, 313 (1906).

Origin of the trap.

The presence of this limestone apparently interbedded with the trap is also of interest as supporting the view usually adopted that the latter rock consists of actual lava-flows—possibly sub-aqueous—and is not of intrusive origin. The clearly amygdaloidal character of many of the beds and the apparent absence of apophyses from among the overlying sedimentary rocks is further evidence in support of this view. The only feature which can be regarded as pointing to a possible intrusive origin is the curious manner in which the overlying fossiliferous sedimentary beds—to use Verchère's expression—" lap round " the igneous mass. This character is noticeable on both sides of the Vihi plain, and is especially well-marked in the neighbourhood of Khunmu, where, as will be seen from the sketch-map, the dip of the sedimentary beds, which in the Guryul ravine is towards the east, gradually bends to S.E. and E.S.E. at Risin. Bedding and dip in the underlying trap is not always clear, but so far as it can be traced seems to follow exactly the same course as in the overlying beds, and the Zebanwan hill-mass appears therefore to be a dome rather than a laccolite. The dome-like forms of both the Zebanwan mass and of Wastarwan may, however, be quite possibly due to local uplifts consequent on movements in the molten material which might naturally be supposed to have existed beneath these great masses of igneous material, thus producing a broad trough now represented by the Vihi plain.

Representatives of Zewan stage in Spiti.

The fact that the Gangamopteris beds have been definitely ascertained to be older than the Protoretepora horizon of the Zewan beds has a further and important bearing on the geology of Spiti, and incidentally on the vexed question of the correlation of the Blaini boulder-bed of the Simla hills.

It has already been pointed out that the Protoretepora horizon of Kashmir is the exact counterpart of the Fenestella shales of Spiti, and the beds between the base of the Zewan stage and the lower Trias in Vihi must therefore be the equivalent of the series extending in Spiti from the base of the Fenestella shales to the Otoceras zone, thus including the conglomerates which underlie the calcareous sandstone at and around Po. The absence of any break between the Zewan stage and the lower Trias in Vihi thus proves that the great Palæozoic unconformity, which has hitherto been regarded as the most marked and persistent feature in Himalayan geology,[1] did not

[1] *Mem. Geol. Surv. Ind.*, XXXVI, p. 51 (1904).

extend into the valley of Kashmir, and if we are right in regarding the Gangamopteris series of Khunmu as the equivalent of the lower Gondwanas of India, it is evident that the conglomerate of Spiti cannot represent the Talchir boulder-bed, but must be much younger, and the last remaining reason for regarding it as of glacial origin and correlating it with the Blaini boulder-bed of Simla now disappears.

Summary.

The Gangamopteris beds of Vihi have been found at Zewan in an apparently continuous section, underlain by trap and overlain by the Zewan stage, which is the equivalent of the Fenestella shales of Spiti. Their age is therefore certainly not younger than upper Carboniferous.

The series is everywhere characterised by the occurrence of chert and, locally, of novaculite, which have been derived from pre-existing limestone by the metasomatic replacement of the carbonate of lime by silica, with perfect preservation of the structure of the original rock. This probably indicates the solfataric stage of the later Palæozoic volcanic period of Kashmir.

The beds at the base of the Zewan stage are highly fossiliferous and are especially characterised by the presence of *Protoretepora ampla* Lonsd.

Above this horizon are limestones containing brachiopods and overlain by shales with fossils characteristic of the Productus shales of other parts of the Himalaya. These are overlain, in the Guryul ravine, by beds with lower Triassic fossils.

The sequence from the base of the Zewan stage up to the Trias is complete and conformable, and there are no signs of the great upper Palæozoic unconformity so universal in the Himalaya.

EXPLANATION OF PLATES.

PLATE 5—

1 = *Gangamopteris* beds of Risin spur.
2 = Zewan stage.
3 = *Productus* shales and Lower Trias.
4 = Muschelkalk (?).

PLATE 7—

1 = Novaculite.
2 = *Gangamopteris* horizon.
3 = Zewan stage.

PLATE 8—

Fig. 1. Oolitic limestone, Risin spur near Khunmu.

" 2. The same under crossed nicols, showing twinning lamellæ of calcite running through grains and ground-mass. The whole field is part of a single crystal of calcite.

" 3. Black chert. The whole rock has been silicified, but retains its original structure.

" 4. The same under crossed nicols.

PLATE 9—

Fig. 1. White novaculite from base of section in Guryul ravine, near Khunmu granular structure still apparent, but not so pronounced as in the black chert (Pl. 8, fig. 3).

" 2. The same under crossed nicols.

" 3. The same rock as Pl. 8, fig. 1, partially changed to chert. Grains of calcite with ragged, corroded edges are seen lying in a matrix of chalcedony, derived by replacement of the calcareous ground-mass by silica, nicols crossed.

" 4. Chalcedony (translucent form of the novaculite) from Mandakpal. Nicols crossed.

ON A VOLCANIC OUTBURST OF LATE TERTIARY AGE IN SOUTH HSENWI, NORTHERN SHAN STATES. BY T. H. D. LA TOUCHE, B.A., F.G.S., *Superintendent, Geological Survey of India.* (With Plates 10 and 11.)

IT is somewhat surprising that in the Northern Shan States, where a fairly complete series of Palæozoic and Mesozoic rocks (with the exception of Cretaceous) has been found, not a single instance of the intrusion of igneous rocks has been discovered in any formation of later age than the Cambrian. The whole of the lapse of time represented by the accumulation of the fossiliferous rocks of the Shan plateau appears to have been one of complete volcanic quiescence, and even beyond the limits of the Shan hills the same conditions seem to have prevailed; for if we except the andesitic intrusions of Wuntho and the serpentines of the Arakan Yoma, the age of which is not precisely known, all the basic igneous rocks of Burma are of Tertiary age.

It is not easy to account for this complete absence of volcanic activity throughout so long a period, for it is certain that considerable earth movements took place from time to time during the accumulation of the stratified deposits; but the explanation probably is that these movements were mainly of a tangential character, resulting in the folding and squeezing together of the strata, and that it was not until Tertiary times that the great dislocations or faults, which are more likely to be accompanied by manifestations of volcanic activity, began to be developed.

During a rapid traverse through the South Hsenwi State early in 1905, the writer found near the village of Man-Sang (22° 26′ : 97° 58′), where there is a large patch of Tertiary silts and sands with seams of coal, numerous traces of the existence in the neighbourhood of basic igneous rocks, many of the watercourses being choked with loose blocks of basalt, but want of time prevented his following the matter up. Mr. R. R. Simpson also, in the course of his examination of

the Man-Sang coal-field, came upon the same rocks,[1] and was of opinion that they were either intrusive in the Tertiary silts, or that the latter had been laid down upon an irregular surface of the basalts. On a second traverse made during the field season of 1905-06, I made a point of visiting the principal exposures of these rocks marked by Mr. Simpson, and spent a couple of days in examining their features.

The igneous outburst which forms the subject of the present paper occurs in a small conical knoll called Loi Han Hun, rising to 3,610 feet above sea-level, and situated about two miles south-west of the village of Nawng-tao (22° 30′: 98° 1′), on the cart-road between Lashio and Mong Yai, the capital of South Hsenwi State. Coming up from the south-east, from the direction of Mong Yai, the hill catches the eye at once by reason of its conical or rather dome-shaped appearance, differing as it does greatly from that of the low undulating mound-like hills formed of the soft Tertiary rocks, which cover the surrounding country. The hill rises to a height of about 700 feet above the general level, whereas the other elevations in the neighbourhood, with the exception of the hill ranges to the north, do not rise to more than 200 or 300 feet. It is, however, apparent at once that it is only the upper part of the hill, which is very steep on all sides, and forms a regular dome, that has a distinctive appearance, for the lower, more gently sloping portion differs in no way from any of the surrounding mound-like elevations. An examination of the structure of the hill at once discloses the cause of this peculiar shape. On searching among the ravines that drain the lower portion of the hill, I found that this is composed of the soft Tertiary silts and sand-rock, among which was a band of carbonaceous clay, a representative of one of the coaly layers that are known to occur in this formation. These beds are nearly horizontal, but have a very slight dip towards the south-east. They are so soft, and the stream beds are so choked with débris from the igneous rocks higher up the hill, that it is by no means easy to find an outcrop of them. Proceeding further up the slope, dykes of hard basalt, radiating in all directions from the central dome, make their appearance on the spurs, some of them extending to considerable distances. Each of the dykes exhibits a well-defined columnar jointing, the columns being horizontal, and their

[1] *Rec. Geol. Surv. Ind.*, XXXIII, p. 144.

polygonal ends appearing on the vertical outer walls of the dykes, which stand out boldly from the surrounding slopes (Pl. 10). I made an attempt to discover whether the rocks in contact had been altered in any way by the intrusion, by digging pits alongside two of the dykes, but the results were not satisfactory. Although the surface soil was perfectly dry, I found that, at a depth of only 2 or 3 feet from the surface, there was a copious discharge of water from the dykes, and the rock in contact with them was a stiff blue clay, which showed no signs of induration or other alteration. There can be no doubt, however, that the dykes are really intrusive.

The central dome-like mass forming the upper part of the hill is built up of dykes and bosses of columnar basalt, in which the columns may be found inclined at all angles to the horizon (Pl. 11). The surface of some of these bosses has a curiously rounded or mammillated appearance, as though the molten rock had been forced up a fissure, and cooled under pressure before it quite reached the surface. In fact, the whole mass bears more resemblance to a *laccolite*, than to a true volcanic pipe or neck. There are slight traces of amygdaloid and vesicular structure in the upper part of the mass, but no signs of actual flows of lava in connection with it, nor could I find any such in the immediate vicinity of the hill. The remains of true flows may be found when the country to the west and north-west is more thoroughly examined, for Mr. Simpson mentions the occurrence of amygdaloid lavas in that direction, but these may have proceeded from a separate orifice, the position of which has not yet been located. It is possible, of course, that the present dome of Loi Han Hun represents only the lower portion of a volcanic neck, the upper, more vesicular portion of which has been removed by denudation; but the mammillated appearance of the bosses seen on the summit of the hill seems to indicate that this was the original surface of the basalt, and the Tertiary rocks through which it is protruded belong to such a very late period that I think it hardly possible that every trace of the upper portion of the plug, if it ever existed, should have disappeared.

The rock of which the dykes and central dome are composed is a dense fine-grained basalt, almost black in colour with a greenish tinge. The specific gravity is 2·941. Under the microscope the ground-mass is seen to consist of minute lath-shaped crystals of plagioclase felspar and minute greenish-yellow granules of augite, which sometimes form aggregates arranged in a roughly radial manner, also

abundant magnetite. Larger crystals of plagioclase, with zonal inclusions of the ground-mass, and granular crystals of olivine, sometimes fissured and partly converted into serpentine, are imbedded in the ground-mass.

This rock differs from that of the Tertiary basalt flows of Shwemyindé hill, opposite Kyaukmyaung on the Irrawadi, about 40 miles above Mandalay, in that the augite in the latter is of a pinkish-brown colour, probably owing to the presence of titaniferous iron-ore, and is not so abundant. Otherwise the constituents of the rock are the same, but there is rather more olivine and much more felspar in the Shwemyindé rock. This has a specific gravity of only 2·699, but its want of density may be partly due to the presence of minute gas pores.

A basalt from the extinct volcano Hawshuenshan (Hoschuen-shan) near Teng-yueh (Momien), in south-west Yunnan, which may be of much the same age as that of Loi Han Hun, is described by Professor v. Lóczy in Graf Bela Szechenyi's *Reise in Ostasien* (Vol. III, p. 379). The rock is described microscopically as consisting of microlites of plagioclase felspar (andesine), imbedded in a glassy paste filled with yellowish or greenish granules of augite and crystals of magnetite. Larger crystals of felspar with zonal inclusions of the ground-mass, and crystals and granules of olivine, much fissured, are scattered through the slide. This rock therefore resembles the basalt of Loi Han Hun very closely in composition, except that the latter contains no glass. Indications of the former existence of a glassy basis are, however, seen in a specimen of amygdaloid basalt collected by Mr. Simpson at Namaklang, about two miles west of Loi Han Hun, probably from a lava-flow.

The older portion of the volcano of Hawshuenshan consists of augite-andesite (*Reise in Ostasien*, Vol. I, p. 771), but no traces of this rock have been found in the Shan States. The lava of the ancient volcano Popa or Puppa, in the Myingyan district, also of upper Tertiary age, is, however, mainly, if not entirely, augite-andesite, and if the relations of the rocks at Hawshuenshan are any guide, it would appear that the basalts belong to a later date of eruption than the andesites, and that the basalts of Loi Han Hun belong to quite a recent period. The Tertiary silts into which they are intruded must represent quite the highest deposits of that era, for they have evidently been accumulated since the principal drainage features of the plateau

were marked out, and the shells they contain are all of very recent fresh-water types, such as *Paludina* and *Planorbis*.

EXPLANATION OF PLATES.

PLATE 10.—Basalt dyke, intrusive in Tertiary rocks, on north side of Loi Han Hun, showing horizontal columnar structure.

PLATE 11.—Columnar basalt, summit of Loi Han Hun, showing inclined position of columns.

DESCRIPTION OF SOME NEW SUIDÆ FROM THE BUGTI HILLS, BALUCHISTAN. BY GUY E. PILGRIM, B.SC., F.G.S., *Geological Survey of India.* (With Plate 12.)

SOME months ago a small collection of vertebrate remains, obtained from the hills 25 miles N.E. of Dera Bugti, was sent down to Calcutta by Major A. McConaghey, I.A., Superintendent of Imperial and District Gazetteers, Baluchistan, and was put into my hands for examination. These fossils proved no less interesting than those collected by Blanford during his brief stay in the Bugti hills and described by Lydekker in the Palæontologia Indica. The former collection yielded several new forms to Lydekker's examination, and the same is the case with the present find.

Amongst the fossils which I have had under examination are two left upper molars and a canine of a new species of *Anthracotherium* of large size and allied to the various large European forms; an upper molar, which is intermediate in character between the two groups of the Anthracotheriidæ and Merycopotamidæ and whose peculiar characters indicate it as a new genus; a mandible representing a new species, which is possibly the same as the last mentioned upper molar; and the front part of a skull containing portions of the maxilla and premaxilla, but of which the tooth crowns have been completely worn away. Its affinities are somewhat obscure, though it is probably Suine. In any case, however, it shows a structure and type of dentition which is unique. The specimen is not described or figured on account of its fragmentary condition. I hope, however, at no very distant time, to have further material in my hands, which may elucidate its structure. Besides these occur several molar teeth and mandibles of *Aceratherium blanfordi* Lyd. and *Aceratherium perimense* Falc. et Caut.

The following is a list of the vertebrate species which we at present know to occur in these beds:—

Mastodon (*Tetrabelodon*) *angustidens* Cuv. *var. palæindicus* Lyd.
Mastodon (*Tetrabelodon*) *pandionis* Lyd.
Mastodon (*Tetrabelodon*) *falconeri* Lyd.

Anthracotherium hyopotamoides Lyd.
Anthracotherium nov. sp. aff. magnum.
Brachyodus giganteus Lyd.
Nov. genus, nov. sp.
Aceratherium blanfordi Lyd.
Aceratherium perimense Falc. et Caut.

Our only information on these beds is due to Blanford's brief visit. He classed them with the lower Manchhars, and therefore considered them as forming the base of the great continuous series of the Siwaliks. Consequently they have very generally been spoken of as pliocene, and the oldest age that has been assigned to them is upper miocene, still regarding them as lower Siwaliks. Their vertebrate fauna is, however, of a character distinctive of the lower miocene or even of an older epoch. The invertebrate fauna points no less in the same direction; out of seven species of freshwater mollusca, which Blanford[1] described from these beds, only one presented any close affinities with recent forms. In this novelty of facies the freshwater mollusca are in striking contrast to those of the upper Siwaliks, in which the species are all living at the present day.

Although Blanford seems finally to have decided that the Bugti beds were lower Siwalik, another possibility had occurred to him. Struck by the absence of the Gaj Series in this area, and perhaps by the fact that there is no apparent unconformity between the Bugti beds and the underlying formations, he suggested[2] that the bone beds might possibly represent a local facies of the Gaj.

This has again been suggested more strongly by my colleague Mr. E. Vredenburg,[3] who remarks on the invariable unconformity between the true Siwaliks and the underlying formations.

If then the Bugti beds represent the Gaj series, they must certainly be placed at the base of the miocene,—the position to which their fauna, both vertebrate and invertebrate, would incline us to assign them.

It is to be hoped, however, that a stratigraphical examination of the ground will before long settle the point definitely.

[1] W. T. Blanford. Hills from Quetta to Dera Ghazi Khan. *Mem. Geol. Surv. Ind.*, XX, pp. 162 and 233 (1883).
[2] W. T. Blanford, *ibid.*, p. 160, footnote.
[3] *Rec. Geol. Surv. Ind.*, XXXIV, p. 92 (1906), footnote.

With this introduction I shall now proceed to the detailed description of the new species. I wish here to express my thanks to Dr. A. Smith Woodward, F.R.S., the Keeper of the Geological Department of the British Museum, for his kindness in placing at my disposal all the British Museum specimens, to which I have wanted to refer, and to Dr. C. W. Andrews, F.R.S., for much kindly help and suggestion during my work. To Miss G. M. Woodward I am indebted for her careful drawings of the specimens.

SUINA SELENODONTIA.

PENTACUSPIDATI.

ANTHRACOTHERIIDÆ.

Genus—ANTHRACOTHERIUM.

Species—ANTHRACOTHERIUM BUGTIENSE nov. sp.

Amongst the remains from Dera Bugti, which have come into my hands, are the two last left upper molars and a canine of a large species of *Anthracotherium*. The two molars are almost unworn, and are in a good state of preservation. The last molar lacks only the summit of the metacone, which has been broken off. Lydekker[1] figured a fragment of a mandible obtained by Blanford from the same or somewhat the same locality, which he referred provsionally to *Anthracotherium magnum* Cuv. It is at least likely, however, that it belongs to the same species as the two upper molars figured in Pl. 12, fig. 1, and to which I have no option but to assign a distinct specific name. The differences between the various European species of *Anthracotherium*, more especially in regard to the structure of their upper molars, is so slight that it is necessary to insist on the various small distinctions between the present tooth and the corresponding teeth of all other specimens which have been described and figured. These forms have not always even received distinct specific names, but have been referred to by the locality, where they were found. Most of them are at present included under the name

[1] *Pal. Ind.*, Ser. X, Vol. II, p. 176 (woodcut) (1883).

Anthracotherium magnum; whether they are all entitled to rank as distinct species or whether many of them are to be regarded as races of *Anthracotherium magnum*, is a wide question and one with which I do not propose to deal here. I have, however, carefully compared such figures and descriptions as have been published and actual specimens where they have been available, and have concluded that the *Anthracotherium* of the Bugti Hills is quite distinct both from the varieties as well as from the types of each of the three large European species, which are generally regarded as separate. These three are,—

Anthracotherium magnum Cuvier, type from Cadibona.
Anthracotherium valdense Kowalesky, type from Rosette.
Anthracotherium illyricum Teller, type from Trefail, Styria.

In their general structure these upper molars agree so precisely with the common type of Anthracotherium tooth that it seems needless to enter into much detail in regard to it. There are the four main cusps with an intermediate cusp between the two anterior ones. Osborn's nomenclature is adopted in the sequel in describing the various cusps, columns or tubercles (see also pages 51—52). The two-external cusps (paracone and metacone) each send out a branch partly in the direction of one another and partly outwardly directed. These branches unite and form an upstanding projection from the external wall of the tooth (mesostyle). Another well-marked projection is seen at the antero-external angle of the wall (parastyle), and another at the postero-external angle (metastyle). Posteriorly the enamel forms a broad cingulum culminating in a median tubercle at the entrance of the antero-posterior valley, and continuing though in a less marked degree round to the inner side, where it joins a tubercle situated at the entrance of the transverse valley. Anteriorly there is also a cingulum, which starts from a well-marked tubercle between the protocone and protoconule and continues right to the inside of the tooth until it, too, joins the tubercle at the entrance of the transverse valley.

There seems only need to compare the present molars with those of the three large European species. From *Anthracotherium hyopotamoides* Lydekker, from the same beds in the Bugti Hills, this species is easily distinguished, not only by its size, but also by the form of the loop connecting the outer columns as also by the presence

of parastyle and metastyle and of a cingulum and tubercles connected with it on all sides of the tooth.

As far as size goes it does not seem very feasible to draw any distinction between either of the four large species. Both *A. illyricum* and *A. valdense* have somewhat larger molars than the type specimen of *A. magnum* from Cadibona, but other forms from the Quercy Phosphorites, from Digoin, from Ufshofen, and from Cadibona itself, which have been assigned to *A. magnum*, attain to as great a size, while Filhol[1] believes that he can trace a transition in the other direction from *A. magnum* into the much smaller *A. alsaticum* Cuvier. Therefore, looking only at its size, the present tooth might easily belong to either of the three species. Teller[2] in his admirable descriptions of *A. illyricum* bases one of the specific distinctions between *A. illyricum* and *A. magnum* and *valdense* on the very irregular trapezoid shape of the Styrian species as compared with the almost rectangular outline of the others. In this respect the present species differs from *A. illyricum* and agrees with *A. magnum* and *valdense*, having squarer corners than is even the case in those species. Other important differences are noticeable on the external wall of m^3, in the size and situation of the outer styles. The foremost of these (parastyle) shows a resemblance to *A. illyricum* as distinguished from *A. magnum* by the fact that it is less closely connected with the outer cusp (paracone). Separating the paracone from the parastyle is a broad valley, which does not bend round posteriorly much, as it does in *A. magnum*, but ends abruptly on reaching the outer wall or is continued only as an indistinct cingulum to the entrance of the transverse valley. *A. valdense* is like *A. magnum* except that the parastyle is only slightly developed. These differences are shown in Pl. XII, fig. 1, of Teller's monograph quoted above.

Regarding the mesostyle, this differs in the Bugti species very markedly from each of the three other species both in its position and in its degree of development. It begins more anteriorly and rises exactly opposite the transverse valley instead of rather behind it, as in *A. magnum*. Further, it is very much smaller; however, it is continued backward into a broad cingulum, which completely encircles

[1] H. Filhol: Phosphorites du Quercy, *Ann. Sci. Geol.*, VIII (1877), p. 175.

[2] F. Teller: Neue Anthracotherien reste aus Sudsteiermark und Dalmatien, *Beit. Pal. Ost. Ung.*, IV, p. 82 (1884).

the base of the metacone and joins the metastyle at the postero-external angle. It is the presence of this broad cingulum and the pronounced metastyle that prevents the tooth base from presenting the irregular outline of *A. illyricum*, in spite of the equally great development in both of the parastyle. Coming now to the metastyle we find that its strongest development occurs in *A. illyricum*. In the present species it is somewhat less developed, but more so than in *A. magnum* and very considerably more so than in *A. valdense*, where it is practically absent. Finally the development of a distinct cingulum on the inner side is very noticeable in the present species as contrasted with the very abrupt termination of the cingulum while rounding both inner corners front and back, in each of the three species compared. We may remark that this inner cingulum is also developed in *A. cuvieri* Pomel from Allier. This species is, however, of smaller relative dimensions than the present one, besides differing in other points.

In m^2 the same differences noticed for m^3 also apply for the most part, but in a very much feebler degree. The valley separating parastyle from paracone terminates abruptly without bending to the rear and the mesostyle is somewhat less pronounced than in the European species; m^2, however, has no cingulum on its inner wall which was so striking a feature in m^3.

The following are the measurements in millimetres of these two molar teeth—

	m^2	m^3
Length of outer wall between the antero-external and postero-external angles	47·3	58·9
Length of inner wall at base of crown . . .	45·5	53·3
Breadth of tooth in front half from crown base of protocone to parastyle	51·8	62·8
Breadth of tooth in hinder half from crown base of hypocone to mesostyle	51·9	60·0
Oblique distance between crown base of hypocone and postero-external angle	47·1	50·3

The canine tooth is represented by the almost unworn distal end broken off 83 mm. from the tip and has a longer diameter of 47 mm. and a shorter one of 42 mm., these being both maxima. The surface possesses two narrow longitudinal ridges opposite one another. The line joining the bases of the ridges is inclined at an angle of about 45° to the directions of the maximum and minimum diameters.

SUINA SELENODONTIA.

TETRACUSPIDATI.

MERYCOPOTAMIDÆ.

Genus—TELMATODON nov. gen.

Species—TELMATODON BUGTIENSIS nov. sp.

The generally reprehensible practice of founding a new genus with only such a limited portion of it in one's hand as a single tooth is here adopted in preference to the equally unsatisfactory alternative of leaving a fine specimen nameless and so increasing the difficulty of indexing and future reference.

This genus is founded on the evidence of a last upper molar tooth which, however, possesses characters so unique as to render it impossible to assign it to any one of the previously known genera. It gives us yet another link between the Ruminantia and the Suina and appears to occupy a position intermediate between the Merycopotamidæ and the Anthracotheriidæ.

The tooth under consideration is entirely preserved with the exception of the outer posterior accessory tubercle (metastyle), which has been slightly abraded, and is in a moderately early stage of wear. The absence of a socket on the posterior side indicates it to have been the last molar.

It is rather broader than long and the length is greater externally than it is internally. This can be seen by reference to the measurements on page 54. It is brachyodont and of the general tetracuspidate selenodont type with four primary columns designated according to Osborn's nomenclature as the protocone, paracone, metacone, and hypocone. The parastyle at the antero-external angle is developed

to an extraordinary degree, as is the case in all the species of *Brachyodus* and *Ancodus*. The metastyle at the postero-external angle is developed in quite an analogous way though to a much less marked extent. The paracone and metacone are connected by a pronounced loop projecting on the external wall and constituting the mesostyle,—another feature of the genus *Brachyodus*. In fact it may be regarded almost as a tooth of *Hyopotamus giganteus* Lydekker (which is undoubtedly a *Brachyodus*) without the anterior intermediate cusp (protoconule). The absence of this fifth cusp, however, makes it impossible, according to our present classification, to place our specimen in the Anthracotheriidæ and compels us in spite of its obviously more bunodont character to make room for it among the Merycopotamidæ. It is noteworthy that there is a trace, faint but very distinct, of the protoconule, so that this genus affords us a perfect passage between the two groups. The peculiar characters of the tooth will be sufficiently gathered from the detailed comparisons with known genera which follow.

Apart from the want of the intermediate cusp or protoconule other differences exist between the present genus and *Brachyodus*. The former is more hypsodont. While *Brachyodus*, of which *Brachyodus onoideus* Gerv. may be considered as the type, possesses a well-marked cingulum on three sides, *Telmatodon bugtiensis* only shows a real cingulum anteriorly; on the internal side the walls of both columns slope outward at so great an angle from the vertical (40°), that, what might otherwise be regarded as a cingulum, is inconspicuous. Further in *Brachyodus onoideus* the external walls of the two external columns (paracone and metacone) are regularly concave, whereas in the present genus they possess a strong, broad ridge. To a slight extent an approximation to both these conditions is to be noticed in *Brachyodus giganteus* Lydekker. Considering the roots of this tooth, of the anterior ones, which alone are visible, the exterior one is single and curved in a remarkable manner, while the internal one has a lateral branch. The external columns and styles are very obliquely situated and a line joining protostyle to metastyle touches both the ridges of the two external columns, forming thus a straight line inclined at an angle of 18° to the line of jaw.

As may have been inferred from the previous remarks, the more bunodont character of this tooth prohibits its being referred either to the Oreodontidæ or to the Dichodontidæ. There remain only its

affinities with the various members of the Merycopotamidæ to be considered. At one time or another three genera have been placed in this family, *Merycopotamus*, *Hemimeryx*, and *Chæromeryx*, although Lydekker has considered that the affinities of the last named are rather with the Dichodontidæ. This tooth resembles Merycopotamus in certain ways, as for example in the ridges on the external side of the outer columns. It is, however, easily distinguished from *Merycopotamus* :

1. By the fact that the angles on either side of the outer columns are not folded over towards one another as in that genus, but are very much more open and separated. The external part of the tooth is, so to speak, less squeezed together than in *Merycopotamus.*

2. The loop connecting the external columns is much more strongly developed than in *Merycopotamus.*

3. In the very much greater development of the parastyle.

4. Whereas in *Merycopotamus* the transverse valley is practically open, in this tooth it is to a certain extent closed externally.

5. In the strong outward slope of the internal surfaces of the protocone and hypocone, as before mentioned, and the consequent absence or apparent absence of a cingulum internally. There is likewise no trace of the external cingulum of *Merycopotamus.*

6. Every vestige of an intermediate cusp has disappeared in *Merycopotamus*, which is not the case in the Bugti genus.

There are many other minor differences, but the ones mentioned will serve to sharply separate the two genera.

The present tooth resembles *Hemimeryx* in the oblique direction of the external surfaces of the outer columns and styles, and in the prominence of the mesostyle. The most important differences are :

1. The absence in *Hemimeryx* of any median ridge on the external surfaces of the outer columns.

2. The incomplete protocone in *Hemimeryx.*

3. The absence of a parastyle in *Hemimeryx.*

4. The much stronger development of a cingulum than is the case in the present genus.

This tooth approximates to that of *Chæromeryx* both in the vestigial trace of a protoconule, which is, however, far more pronounced in that genus, and in the compression of the loop connecting the outer columns so that the surfaces of these columns are more ample. Moreover, both genera possess the median ridge on these columns

though it is much wider and more convex in *Telmatodon*. Differences from *Chæromeryx* exist:

1. In the entirely different form of the outer columns. Their general line is more oblique than in that genus, but the most striking point is that in *Chæromeryx* the outer crescents are very much less squeezed together, while the ridges on either side, especially the posterior one, are only slightly pronounced. In consequence of this, their outward concavity is very trifling, which feature gives to *Chæromeryx* that similarity to the Ruminantia which is wanting in *Telmatodon*.

2. In the greater development of the parastyle.

3. In the outward slope of the internal surfaces of the inner columns and the reduction of the cingulum in the same way that has been noticed in comparing my specimen with the other members of the family.

Sufficient has been said to indicate certain marked affinities to each of these three genera, so that, in view of its tetracuspidate character, my specimen can easily be placed in the family of the Merycopotamidæ, although, as explained above, its affinities decidedly lean also in the direction of the Anthracotheriidæ, giving us evidence, like *Chæromeryx*, in the gradual atrophy of the protoconule, of an evolutionary transition from the one of these two families to the other.

The following are the measurements in millimetres of the tooth described above:—

Length of outer wall between the antero-external and postero-external angles	39·1
Length of inner wall at base of crown	34·0
Breadth of tooth in front half from crown base of protocone to parastyle	46·1
Breadth of tooth in hinder half from crown base of hypocone to mesostyle	41·5
Oblique distance between crown base of hypocone and postero-external angle	37·0

Mandible.

It is with great hesitation that I provisionally refer the fragment figured in Pl. 12, figs. 4 and 5, to the same genus as the upper molar described above. Few of the portions, which afford good generic characters, are present in the specimen. It seems, however, to present

differences from the mandible of any other genus, and as its size and general structure are such as might reasonably lead us to suppose that it belonged to the same species as the molar tooth of *Telmatodon*, I have thought it better to assign it to some definite position until further evidence should come to hand.

It is broken off immediately in front of the last lower molar, and although portions of the mandible posterior to the tooth are present, the basal part just behind the notch is absent, so that it is impossible to say whether it possessed a descending flange or not.

Lydekker described[1] and figured three mandibles obtained from a locality in the Bugti Hills very near to and possibly even the same as that from which the present specimens come. He assigned these provisionally to *Anthracotherium hyopotamoides* Lydekker and *Hyopotamus giganteus* Lydekker. These mandibles belonged to a larger animal than this, are distinctly more brachyodont and give indications of having possessed a second tubercle to the talon of the last molar; though this cannot be positively asserted. If either of them are correctly referred to *Anthracotherium*, this second tubercle should certainly be present as it is characteristic of the genus. The genus *Brachyodus* also, as Andrews[2] has observed, has very distinct traces of this second tubercle, in which respect *Anthracotherium* and *Brachyodus* differ from *Ancodus*. In the talon of the present tooth no second tubercle can be traced. My other reasons for not considering this mandible as that of a *Brachyodus* are that it is more hypsodont, that the external wall of the tooth more nearly approaches the vertical, that the outward bending of the loop of the talon is greater, and finally on account of the character of the sculpturing of the surface of the enamel, which is rugose instead of being in fine longitudinal wavy ridges. In this it seems to agree with the upper molar just described. On the other hand it differs from *Ancodus* in the rugose sculpturing of the enamel (in *Ancodus* the enamel is unsculptured), in the greater prominence of the cingulum, and in the more rounded nature of the external crescents. The cingulum is not, however, prominent in the tooth under consideration. It is wanting entirely on the internal edge, but is well marked on the antero-external angle and on the outer side of the talon.

[1] *Pal. Ind.*, Ser. X, Vol. II, pp. 154 and 163, Pl. XXV (1884).

[2] C. W. Andrews: *Geol. Mag.* (4), VI, p. 484 (1899).

Considering now its affinities to the Merycopotamine group, it seems to approach *Merycopotamus* in its hypsodonty, in the outward bending of the crescent of the talon (although this is less marked than is the case in Merycopotamus), and in the character of the jaw, so far as it can be observed. This is extremely wide and massive around the teeth, but suddenly thins basally and still more suddenly posteriorly. Whether it possessed the prominent descending flange of *Merycopotamus* or not, the posterior notch must have been very deep, as it is unlikely that a bone so thin as is the case within the posterior part of this mandible would have been fractured within such a short distance of the base, the inference then being that the base must have extended some considerable distance below the fracture. On the whole its Merycopotamine affinities seem to justify my provisionally placing it in the position that I have. The characters will be sufficiently gathered from the figures (Pl. 12, figs. 4 and 5) and the above description.

EXPLANATION OF PLATE.

PLATE, 12, FIG. 1.—*Anthracotherium bugtiense* nov. sp., last two left upper molars $\frac{2}{3}$ nat. size.

" FIG. 2.—*Anthracotherium bugtiense* nov. sp., canine $\frac{2}{3}$ nat. size.

" FIG. 3.—*Telmatodon bugtiensis* nov. sp., last left upper molar. $\frac{2}{3}$ nat. size.

" FIG. 4.—*Telmatodon bugtiensis?* Left ramus of mandible with last molar (side view) $\frac{2}{3}$ nat. size.

" FIG. 5.—The same (surface view) $\frac{2}{3}$ nat. size.

PERMO-CARBONIFEROUS PLANTS FROM KASHMIR. BY A. C. SEWARD, F.R.S., *Professor of Botany, Cambridge.* (With Plate 13.)

IN 1905 a short account was published of plants collected by Dr. Noetling at Khunmu in the Vihi valley, S. E. of Srinagar. All the specimens, with the exception of a single impression referred with some hesitation to the genus Psygmophyllum, were identified as fragments of a new species of Gangamopteris, *G. kashmirensis*.[1] The conclusion arrived at, so far as it was possible to base an opinion on the meagre data available, was that the Khunmu fossils indicated a geological horizon at least as low as the Talchir series. Two new species of fishes, *Amblypterus kashmirensis* and *A. symmetricus*, and one new species of Labrinthodont, *Archegosaurus ornatus*, were described by Dr. Smith Woodward and compared by him with Permian species from European localities.[2] During the summer of 1906 Mr. Hayden collected additional material from the Gangamopteris beds in the neighbourhood of Khunmu and from other localities. This collection was submitted to me for examination by the Director of the Indian Geological Survey, from whom I have also received a proof of Mr. Hayden's paper on "The stratigraphical position of the Gangamopteris beds of Kashmir." The object of Mr. Hayden's visit to Khunmu was to determine the relation of the plant-beds to certain fossiliferous marine strata in the same area. Plants were obtained from the following beds:—A.—An upper band of carbonaceous shale on the main Gangamopteris horizon exposed on the Risin Spur at the mouth of the Nagowan ravine, ⅛ mile N. W. of Khunmu, Viti (Dr. Noetling's locality from which were obtained the plants already described). B.—A lower band of carbonaceous shale at the same place. C.—Bed No. 3, Zewan Spur, near the villages of Panduchak and Zewan, Vidi. From this bed Mr. Oldham and Mr. Hayden collected specimens of Gangamopteris identical with those from locality A. D.—Bed no. 13, a hard siliceous shale exposed in the section which includes bed No. 3 (C). E.—Carbonaceous shale on the left side of Guryul ravine.

[1] Seward and Woodward (05).
[2] *ibid.*

Mr. Hayden has shown that the age of the Gangamopteris beds depends on that assigned to the Zewan rocks; he writes:—"All that we can say at present is that the Gangamopteris beds are not younger than Upper Carboniferous and may belong to the base of that subdivision or even to the Middle Carboniferous." (See *ante*, p. 36.) It only remains to write a report on the palæobotanical records furnished by these Kashmir strata.

With a very few exceptions all the plant fragments belong to leaves of *Gangamopteris kashmirensis*, a species which must have grown in profusion and almost to the exclusion of other plants. The following represents the result of the examination of the material from the five Kashmir localities:—

A.—*Gangamopteris kashmirensis*; one specimen of Cordaites leaf. Most of the material comes from this locality.

B.—A single specimen of *G. kashmirensis*.

C.—This, the second richest locality, has afforded *G. kashmirensis* in abundance, together with fragments of *Psygmophyllum Hollandi* and Cordaites.

D.—A few fragments including Gangamopteris and Cordaites.

E.—This bed has so far yielded no satisfactory specimens, but some of the fragments appear to be identical with *G. kashmirensis*.

Description of Specimens.

Gangamopteris kashmirensis Sew.—The majority of the specimens from the richest localities A and C add nothing to our knowledge of this species, but a few examples occur which enable us to amplify the definition of the species as regards the form of the apex of the frond, which was not preserved in any of the specimens previously obtained.

In the definition of the species based on the earlier collection the apical portion of the leaf is described as broadly lanceolate; this is borne out by such a specimen as that represented in fig. 2, Pl. 13, but the example shown in fig. 1, which is broken just short of the tip, possesses a much more gradually tapered apex which can hardly be described as broadly lanceolate. The apex represented in fig. 1 is distinct from that of any species of Gangamopteris or Glossopteris hitherto figured, and it affords some confirmation of my description of the Khunmu plant as a new species. The secondary

veins are indicated in the lower part of the fragment, but from the upper portion they have been entirely obliterated. The shorter and broader form shown in fig. 2 (loc. A) exhibits the characteristic venation with greater clearness. A second example of the narrower type of apex was obtained from locality D.

PSYGMOPHYLLUM HOLLANDI sp. nov. Pl. 13, figs. 3—6.

My former account of Kashmir plants contains a description and a figure of a specimen described as *? Psygmophyllum* sp. The impression was described as part of the lamina of a leaf apparently divided into two symmetrical halves. Specimens from localities C and D supply further information in regard to this type of leaf, and, if I am right in regarding the new specimens as specifically identical with the solitary example hitherto described, they lend support to the generic designation adopted.

Fig. 3, Pl. 13, from locality C represents what is probably half a lamina similar to the specimen shown in fig. 3 of my former paper. The venation is not distinctly preserved, but it appears to be that of Psygmophyllum. This fragment regarded by itself might equally well be placed in the genus Ginkgo, but the evidence afforded by others is more in accordance with the adoption of the name Psygmophyllum. It is, however, difficult to speak with confidence as regards the choice between the genera Baiera, Ginkgo, and Psygmophyllum: it is indeed not improbable that the three plants are all members of the same group, the Ginkgoales. The specimen shown in fig. 4 consists of part of a leaf with a short basal portion and a bilobed lamina which represents half a wedge-shaped leaf divided into two symmetrical halves by a deep median sinus. The dotted line in the drawing indicates the supposed outline of the complete leaf; a few veins are obscurely indicated in one part of the lamina.

Fig. 5, Pl. 13 (loc. C), shows part of two leaves like that represented in fig. 4; that to the left of the axis is the best specimen so far obtained. From the axis which lies between the leaves short branches are given off at *a* which agree in breadth with the basal part of the leaf represented in fig. 4 and may be the remains of leaf-bases. Although there is no absolute proof of a connection between the axis and leaves, I am inclined to regard both as parts of the same plant. The fragment shown in fig. 6 is from locality D; this may be a piece of a leaf like that of figs. 4 and 5. Traces of veins are faintly preserved.

The specimen represented in fig. 5 bears a striking resemblance to *Psygmophyllum Kidstoni*[1] from the Lower Karroo beds of Vereeniging, South Africa, and this similarity constitutes an argument in favour of the use of the designation Psygmophyllum. This genus ranges from the Permian to the Lower Carboniferous and is thus not inconsistent with the views expressed by Hayden as to the geological age of the Kashmir rocks.

It is noteworthy that the pinnules of a plant described by Schmaulhausen from Upper Devonian strata of Russia as *Archæopteris archetypus*[2] are very similar, except in their smaller size, to the leaves of the Indian species.

CORDAITES sp.

The small paralleled veined leaf from locality A represented in fig. 7 (4·7 cm. long and 1·1 cm. broad) has an obtuse but imperfect apex and a truncated base: the veins are rather obscure; at the apex they are seen to diverge very slightly towards the edge of the lamina. In the example from locality C, fig. 8, the apex is clearly preserved and the veins are fairly distinct. These specimens present a close resemblance to the smaller leaves referred by Feistmantel to *Noeggerathiopsis Hislopi* from the Lower Gondwana series of India[3] and may be specifically identical with that species: for reasons which it is not necessary to recapitulate here I prefer to adopt the generic name Cordaites in preference to that of Noeggerathiopsis on the ground that Neoggerathiopsis is probably not distinct from the widely distributed northern type. The smaller of the leaves figured by Schmaulhausen[4] as *Rhiptozamites Goepperti* from Russian rocks originally assigned to a Jurassic age, but more recently, and no doubt correctly, transferred by Zeiller[5] to a Permian horizon, presents a close resemblance to the Kashmir fossils.

Conclusion.

As regards the bearing of this additional material on the question of geological age, Psygmophyllum is consistent with any horizon

[1] Seward (03), Pl. XII, p. 93.
[2] Schmaulhausen (94), Pl. II.
[3] Feistmantel (79), Pl. XIX.
[4] Schmaulhausen (79), Pl. VII, figs. 23—27.
[5] Zeiller (96).

from the Permian down to the Lower Carboniferous. Cordaites has a similar range; Gangamopteris is characteristic of the Lower Gondwana series in India and of rocks occupying a corresponding position in other parts of Gondwana Land, but it is not surprising to find a new type of the genus in beds which are at least not younger than the upper division of the Carboniferous system.

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EXPLANATION OF PLATE.

(All the figures are reproduced nature size.)

PLATE 13, FIGS. 1 & 2.—*Gangamopteris kashmirensis*, from Risin spur (loc. A).

" " 3—6.—*Psygmophyllum Hollandi* sp. nov.
Figs. 3—5 from Zewan spur (loc. C).
Fig. 6.—Zewan spur (loc. D).

" " 7 & 8.—*Cordaites sp.*
Fig. 8.—Risin spur (loc. A).

G. I. C. P. O. No. 47 D. G. Surv.—3-12-07—700.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part. 2.] 1907. [December,

THE MINERAL PRODUCTION OF INDIA DURING 1906.

BY T. H. HOLLAND, F.R.S., *Director, Geological Survey of India.*

CONTENTS.

I.—INTRODUCTION.

THIS summary of the returns for Mineral Production in India during 1906 is given in the form adopted for 1904 (*Records*, Vol. XXXIII, Part 1) and for 1905 (*Records*, Vol. XXXIV, Part 2). Fuller details concerning the principal mineral occurrences of the country known up to the end of 1903 are given in the Review of Mineral Production for the years 1898 to 1903 (*Records*, Vol. XXXII, Part 1). Later additions to our knowledge of mineral occurrences in India will be summarised in the Quinquennial Review to be published as soon as possible after the close of the period 1904—1908.

A full statement of production and statistics regarding labour at the mines regulated by the Indian Mines Act of 1901 has been published with the Annual Report of the Chief Inspector of Mines. The totals given by the Chief Inspector both for output and labour refer only to mines under the Act, and thus do not include the production of mines in Native States, or the output of numerous minor products raised from the superficial workings to which the Act has not yet been applied. The present statement, however, includes as many of these products as have been reported by Local Governments and States, the minerals being divided as before into two groups, namely,—

Group I for which approximately full returns are obtainable, and

Group II for which the returns are admittedly incomplete or only approximately estimated.

For the future all returns for mineral production will be sent by Local Governments and Political Agents direct to the Geological Survey Office, and it is hoped that this system will permit of a more thorough and prompt check of the figures with a view of increasing Group I at the expense of Group II. It will be noticed that a certain number of corrections have been made in the figures reported for 1905, and where changes have been made in the method of estimating values for 1906, corresponding corrections have been made in the figures for 1905.

Total value of production.

Although there has been considerable variations in the production during the past year the total value of the minerals of Group I for 1906 exceeds that for the same minerals raised in 1905 by £622,870, or an increase of 10·9 per cent. (see table 1).

Prospecting and mining concessions.

There was a considerable increase in the number of concessions granted for prospecting and mining, the total number of licenses and leases granted in Government lands having risen from 189 in 1905 to 252 in 1906. The licenses and leases granted in alienated lands and in the various States have not been reported.

TABLE 1.—*Total Value of Minerals for which Returns of Production are available for the years 1905 and 1906.*

MINERAL.	1905.	1906.
	£	£
Gold	2,416,971	2,230,284
Coal (*a*)	1,419,443	1,912,042
Petroleum (*a*)	604,203	574,238
Salt (*a*)	441,392	420,901
Saltpetre (*b*)	235,723	270,547
Manganese-ore (*b*)	248,309	435,268
Mica (*b*)	142,008	259,544
Ruby, Sapphire, and Spinel . .	88,340	96,867
Jadestone (*b*)	45,474	64,433
Graphite	16,890	10,009
Iron-ore (*a*)	13,827	11,341
Tin-ore (*a*)	9,917	13,799
Chromite (*a*)	3,482	7,188
Diamonds	2,474	5,166
Magnesite (*a*)	550	488
Amber	945	709
TOTAL .	5,689,948	6,312,818

(*a*) Spot prices. (*b*) Export values.

II.—MINERALS OF GROUP I.

Chromite.	Graphite.	Manganese-ore.	Salt.
Coal	Iron-ore.	Mica.	Saltpetre.
Diamonds.	Jadeite.	Petroleum.	Tin.
Gold.	Magnesite.	Ruby, Saphire, and Spinel.	

Chromite.

There was a marked increase in the production of chromite in Baluchistan, namely, from 2,708 tons, valued at £3,482, in 1905, to 4,375 tons, valued at £7,188, in 1906. Table 2 gives the figures since 1903. The values reported for 1906 also show an increase in the average value per ton as well as in the total.

TABLE 2.—*Production of Chromite in Baluchistan since the commencement in 1903.*

YEAR.	Quantity.	*Value.*	Value per ton.
	Tons.	£	Shillings.
1903	248	327	23·0
1904	3,596	4,137	23·0
1905	2,708	3,482	25·7
1906	4,375	7,188	32·9

Coal.

Total production, value, and average price of coal.

The output of coal for 1906 shows that the activity previously reported has again been extended, the total production having risen from 8,417,739 statute tons in 1905 to 9,783,250 tons in 1906, an increase of 16·2 per cent. On account of the higher prices maintained throughout the year there has been a still greater proportionate increase in reported spot value. The total value returned for 1905 was £1,419,443; for 1906 the total reported was £1,912,042, that is an increase of 34·7 per cent. The average price per ton reported as the spot value of

Indian coal in 1905 was 3*s.* 4*d.*; in 1906 the average of the figures returned was 3*s.* 11*d.* per ton. The spot prices naturally do not correspond to fuel value, for Bengal coal, which is, all round, the best worked, brought an average price during 1906 of only 3*s.* 6*d.*

TABLE 3.—*Production and Value of Coal during the years 1904—1906.*

YEAR.	Quantity.	Total Value at the Mines.		Average Value per ton at the Mines.	
	Statute Tons.	*Rupees.*	£	*Rs. as.*	*s. d.*
1904	8,216,706	*2,09,82,407*	1,398,826	*2 9*	3 5
1905	8,417,739	*2,12,91,649*	1,419,443	*2 8*	3 4
1906	9,783,250	*2,86,80,655*	1,912,042	*2 15*	3 11

TABLE 4.—*Provincial Production of Coal for the years 1904—1906.*

PROVINCE.	1904.		1905.		1906.	
	Quantity.	*Value.*	Quantity	*Value.*	Quantity.	*Value.*
	Statute Tons.	£	Statute Tons.	£	Statute Tons.	£
Baluchistan . . .	49,867	*27,308*	41,725	*23,658*	42,164	*22,299*
Bengal	7,063,680	*1,015,147*	7,234,103	*1,042,223*	8,617,820	*1,521,057*
Burma	1,105	*294*	...	...	1,222	*305*
Central India . . .	185,774	*47,060*	157,701	*40,137*	170,292	*41,898*
Central Provinces . .	139,027	*43,664*	147,265	*44,452*	92,848	*26,296*
Eastern Bengal and Assam	266,765	*84,592*	277,065	*87,826*	285,490	*90,431*
Hyderabad . . .	419,546	*150,345*	454,294	*140,074*	467,923	*167,606*
Kashmir . . .	270	(*a*)	...	...	...	...
Punjab	45,594	*22,144*	62,622	*34,166*	73,119	*36,301*
Rajputana (Bikanir)	45,078	*8,272*	42,964	*6,907*	32,372	*5,849*
TOTAL .	**8,216,706**	*1,398,826*	**8,417,739**	*1,419,443*	**9,783,250**	*1,912,042*

It will be noticed from tables 5, 6, and 7 that the increase in the total is mainly contributed by the Gondwana fields, especially those of Bengal. The Jherria field has at last taken the lead among the coalfields, while the Raniganj field, which has hitherto been the greatest producer, drops to second place. An interesting development is that of the Pench Valley field in the Central Provinces, showing an output of 32,102 tons in spite of the imperfect railway facilities so far serving the field.

TABLE 5.—*Origin of Indian Coal raised during 1904—1906.*

—	1904.	1905.	1906.
	Statute Tons.	Statute Tons.	Statute Tons.
From Gondwana coalfields . . .	7,808,027	7,993,363	9,348,883
From Tertiary coalfields . . .	408,679	424,376	434,367
TOTAL, Statute Tons .	**8,216,706**	**8,417,739**	**9,783,250**
Total, Metric Tons .	*8,348,561*	*8,552,422*	*9,940,246*

TABLE 6.—*Output of Gondwana Coalfields during 1904—1906.*

COALFIELDS.	1904.		1905.		1906.	
	Statute Tons.	Per cent. of Indian Total.	Statute Tons.	Per cent. of Indian Total.	Statute Tons.	Per cent. of Indian Total.
Bengal—						
Daltonganj . .	50,517	·61	71,294	·85	87,768	·89
Giridih . . .	773,128	9·41	829,271	9·85	803,321	8·21
Jherria . . .	2,889,504	35·17	3,070,588	36·48	4,076,591	41·67
Rajmahal . .	274	...	414	..	577	...
Raniganj . .	3,350,257	40·77	3,262,536	38·77	3,650,563	37·32
Central India—						
Umaria . . .	185,774	2·26	157,701	1 87	170,292	1·74
Central Provinces—						
Bellarpur . .	90	...	148	·02	916	·34
Pench Valley . .	...	...	1,104		32,102	
Mohpani . .	26,618	·32	22,998	·27	27,503	·28
Warora . . .	112,319	1·37	123,015	1·46	32,327	·33
Hyderabad—						
Singareni . .	419,546	5·11	454,294	5·38	467,924	4·78
TOTAL .	7,808,027	95·02	7,993,363	94·95	9,348,884	95·56

TABLE 7.—*Production of Tertiary Coal in 1904—1906.*

COALFIELDS.	1904.		1905.		1906	
	Statute Tons.	Per cent. of Indian Total.	Statute Tons.	Per cent. of Indian Total.	Statute Tons.	Per cent. of Indian Total.
Baluchistan—						
Khost . . .	38,574	·47	34,140	·41	32,500	·33
Sor Range, Mach, etc.	11,293	·14	7,585	·09	9,664	·10
Burma—						
Shwebo . . .	1,105	·02	*Nil*	...	...	...
Upper Chindwin	*Nil*		*Nil*	...	1,222	·01
Kashmir—						
Ladda . . .	270		*Nil*	...	...	...
Eastern Bengal and Assam—						
Makum . . .	266,265	3·25	276,577	·29	285,402	2·92
Smaller fields . .	500		488		88	
Punjab—						
Salt Range . .	45,258	·55	61,618	·75	57,438	·75
Attock district .	336		715		10	
Shahpur " . .	...	...	289		15,671	
Rajputana—						
Bikanir . . .	45,078	·55	42,964	·51	32,372	·33
TOTAL .	408,679	4·98	424,376	5·05	434,367	4·44

Exports. The external demand for Indian coal has increased with the general rise of prices, and the reduction of Japanese supplies has permitted a sensible increase of the exports to Singapore. The total quantity exported during 1906 for the first time exceeds a million tons (see table 8).

TABLE 8.—*Exports of Indian Coal during 1904—1906.*

Exported to	1904.	1905.	1906.
	Tons.	Tons.	Tons.
Aden	31,620	29,312	19,233
Africa, East	21,263	15,034	13,543
Ceylon	360,697	376,853	416,202
Straits Settlements	144,545	229,230	317,655
Sumatra	32,810	33,859	71,482
Other countries	11,875	99,472	169,678
TOTAL .	602,810	783,760	1,007,793

The large quantities sent to "Other countries" during 1905 and 1906 are mainly due to a sudden demand for Indian coal in China, mainly because of the curtailment of supplies from Japan.

Imports.

Imports of coal are still small though they increased slightly from 188,677 tons in 1905 to 215,712 tons in 1906.

Consumption.

The consumption of Indian coal on Indian Railways was 2,878,281 tons in 1906, which was 29·4 per cent. of the total production, as against an average of 29·8 per cent. for the previous five years. The total consumption of coal increased by 1,161,850 tons, but, on account of the great increase in export, the amount of Indian coal consumed in the country increased at a slightly lower rate than the production (table 9).

Labour.

The average daily attendance at Indian coal mines in 1906 was 99,138, and the average output per person employed 98·68 tons, as against 93·5 tons in 1905 and 88·6 tons in 1904. The low results recorded for years before 1905 are due partly to defective returns, but during the last two years the improvement in output per person employed faithfully reflects the advantages of mechanical assistance in handling the coal. Improvement is shown in the total as well as in the output per person employed below ground. In 1905 the output per person employed below ground was 136·6 tons; in 1906 the output rose to 145·0 tons.

TABLE 9.—*Relation of Consumption to Production of Coal during 1904—1906.*

YEAR.	Total Consumption of Coal in India.	Consumption of Indian Coal in India.	
		Quantity.	Percentage of Indian Production.
	Tons.	Tons.	
1904	7,884,140	7,613,896	92·7
1905	7,846,554	7,633,979	90·7
1906	9,008,404	8,775,457	89·7

Diamonds.

The diamonds obtained in the Central Indian States of Panna, Charkhari, and Ajaigarh during 1906 were valued at £5,160, which is a marked improvement on the values reported for previous years (table 10).

TABLE 10.—*Production of Diamonds in Central India.*

YEAR.	Quantity.	*Value.*
	Carats.	£
1904	286·48	*2,636*
1905	172·41	*2,474*
1906	305·91	*5,160*

The principal increase is due to the State of Panna, which contributed diamonds to the value of £4,348 in 1906, against only £1,829 in 1905. The daily average attendance of workers is returned as 2,051 for the whole diamond fields during 1906, against 1,890 reported for 1905.

Gold.

The year 1906 marks the first interruption in the increase of gold production in Mysore, the total value of the output having fallen below that for 1905 by £195,821. The returns for other areas shown in table 11 call for no special remark in an annual statement.

TABLE 11.—*Quantity and Value of Gold produced in India during 1904—1906.*

PROVINCE.	1904.		1905.		1906.	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Ounces.	£	Ounces.	£	Ounces.	£
Bombay—						
Dharwar .	...	...	93	321	60	232
Burma—						
Pakôkku .	...	...	1½	7	1·3	5
Myitkyina .	216	810	620	2,412	2,300	8,850
Hyderabad .	10,559	40,624	13,167	50,060	13,782	52,801
Mysore . .	607,57	2,323,183	616,758	2,363,457	565,208	2,167,636
Punjab . .	370	1,379	176	703	190	746
United Provinces	23	83	2½	11	3·8	14
TOTAL .	618,746	2,366,079	630,818	2,416,971	581,545	2,230,284

TABLE 12.—*Output of Gold from the Hutti Mine, Hyderabad.*

YEAR.	Quantity.	*Value.*
	Ounces.	£
1903	3,809·4	14,505
1904	10,558·6	40,624
1905	13,167	50,060
1906	13,784	52,801
TOTAL .	41,319	157,990

Graphite.

The total production of crude graphite in 1906 was returned as 2,600 tons, valued at £10,009, against 2,324 tons, valued at £16,890, in 1905.

Iron-ore.

The production of iron-ore during 1906 was only 74,106 tons, against 102,529 tons in 1905 and 71,608 tons in 1904. The output is dominated by the quantity raised for the Barakar iron-works which is the only institution smelting on European lines. For the Barakar works the quantity raised in 1906 was returned as 69,397 tons. There was a considerable increase in the number of small native-furnaces in the Central Provinces, the total for 1906 being 379, against 279 for 1905. Returns for labour have been received from most districts and States. The average daily attendance in 1905 amounted to 2,060 and in 1906 to 3,269.

TABLE 13.—*Quantity and Value of Iron-ore raised during the years 1904—1906.*

PROVINCE.	1904.		1905.		1906.	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons.	£	Tons.	£	Tons.	£
Bengal . . .	65,115	*9,698*	97,698	*12,538*	69,397	*10,085*
Other Provinces and States	6,493	*1,731*	4,831	*1,289*	4,709	*1,256*
TOTAL, Statute Tons & £	**71,608**	*11,429*	**102,529**	*13,827*	**74,106**	*11,341*
Total, Metric Tons .	*72,757*	...	*104,174*	...	*75,295*	...

Jadeite.

There was a slight decrease in the production of jadeite in the Myitkyina district of Upper Burma due to scarcity of labour; the returns for 1906 showed a production of 2,214½ cwts. only, against 2,685

cwts. in 1905. The trade through Rangoon, however, showed a marked increase in the value of the mineral exported as shown in table 14.

TABLE 14.—*Export of Jadestone through Rangoon during the years 1902—1906.*

YEAR.	Weight.	*Value.*	Value per cwt.
	Cwts.	£	£
1902	3,843	36,850	9·59
1903	2,192	50,582	23·08
1904	2,869	43,946	15·32
1905	2,342	43,474	18·56
1906	2,566	64,433	25·11
Average	2,762	47,857	17·33

The average daily attendance of workers at the jadestone quarries in Myitkyina during 1905 was 1,085, and during 1906, 1,038.

Magnesite.

The amount of magnesite raised in the Chalk Hills near Salem in 1906 was 1,832 tons, against 2,063 tons in 1905. The local value of the mineral is returned as only Rs. 4 per ton, and this figure has been taken for estimating the value of the magnesite raised during previous years at the same place. There was an average daily attendance at the Salem magnesite quarries during 1905 of 105 workers; for 1906 the average reported is 87.

Manganese-ore.

The most conspicuous increase in production during the past year was in manganese-ore. The total returned for 1906 was 495,730 tons, against 253,896 tons in 1905 and only 150,297 tons in 1904. The total returned for 1906 is probably slightly below the actual, as no

production has been reported from two of the States in which prospecting operations have been carried on actively, but it will be possible to introduce these corrections next year.

The heavy production was, of course, due to the maintenance of high prices in Europe and America; low-grade ores that were sold at a profit last year would not have paid the freight charges in 1904 and the early part of 1905. During 1904 the unit value of manganese-ores carrying over 50 per cent. Mn at United Kingdom ports was only about 9*d.* to 9½*d.*; but about April 1905 there was a tendency for prices to rise, and by August 1905 the unit value was 10*d.* to 11*d.*, rising to 1*s.* for the last quarter of 1905. In 1906 there was a further increase to 1*s.* 1*d.* for the first quarter, and about 1*s.* 2*d.* during May and June, whilst before the close of the year the first-grade ore brought 1*s.* 4½*d.* per unit. Thus the prices were nearly doubled in two years, with the result that larger quantities of the lower grades have been raised and exported, while new quarries have been opened, and great activity in prospecting has followed. India is now probably the largest producer of high-grade manganese-ore, exporting about as much as was obtained from Russia before her mines were so disorganised by internal political disturbances.

Table 15 shows the provincial production for 1906 compared with that for 1904 and 1905.

TABLE 15.—*Production of Manganese-ore for 1904—1906.*

PROVINCE.	1904.	1905.	1906.
	Statute Tons.	Statute Tons.	Statute Tons.
Bombay	*Nil*	......	7,517
Central India	11,564	*30,251*	50,074
Central Provinces	85,034	*150,950*	320,759
Madras	53 699	*63,695*	117,380
TOTAL, Statute Tons	**150,297**	*253,896*	**495,730**
Total, Metric Tons	*152,708*	*257,969*	*503,684*

The labour returns for 1905 show an average daily attendance at manganese-ore quarries of 6,811, while for 1906 the total rose to 12,607, exclusive of the workers employed in Sandur and Mysore.

Mica.

The great increase in the weight of exported mica which was referred to last year (*Rec. Geol. Surv. Ind.*, XXXIV, 57) was due to an error in the returns; the correct figure for 1905 was 25,837 cwts.; but during 1906 the exports were more than doubled in weight and largely though not proportionately increased in value. The total weight of mica exported in 1906 was 54,193 cwts., valued at £258,782, against 25,837 cwts., valued at £142,008, in 1905. Table 16 shows the figures for the past five years.

TABLE 16.—*Exports of Mica during the five years 1902—1906.*

YEAR.	Weight.	Value.	Value per cwt.
	Cwt.	£	£
1902	17,786	76,056	4·28
1903	22,106	90,297	4·09
1904	18,250	83,183	4·56
1905 . . .	25,837	142,008	5·50
1906	54,193	258,782	4·78

It is satisfactory to notice that the returns for production are now in fair agreement with the more accurate figures obtainable for exports. There are still a few areas from which only imperfect figures are obtainable, and the practice of stealing from waste-heaps and mines, which formerly helped to accentuate the great difference between reported production and export, has been considerably reduced. Table 17 shows the provincial returns for 1904, 1905, and 1906.

TABLE 17.—*Provincial Production of Mica for 1904—1906.*

PROVINCE.	1904.	1905.	1906.
	Cwts.	Cwts.	Cwts.
Bengal	14,601	14,601	22,360
Madras	8,280	8,280	24,420
Rajputana	2,760	2,760	5,763
TOTAL .	25,641	25,641	52,543

The returns for labour show for 1905 a total average daily attendance at mica mines of 15,244 workers; for 1906 the total was 15,723.

Petroleum.

There was a slight drop in the production for 1906 as compared with 1905; but, as shown in table 18, a considerable increase as compared with the petroleum produced in 1904.

TABLE 18.—*Production of Petroleum during 1904—1906.*

PROVINCE.	1904.	1905.	1906.
	Gallons.	Gallons.	Gallons.
Burma	115,903,804	142,063,846	137,654,261
Eastern Bengal and Assam . .	2,585,920	2,733,110	2,897,990
Punjab	1,658	1,488	871
TOTAL .	118,491,382	144,798,444	140,553,122

The decrease in production was due mainly to the Yenangyat and Singu fields in Burma (see table 19) although in the latter area the output was artificially restricted. The local value is estimated at about one anna (1*d.*) per gallon of crude oil.

TABLE 19.—*Production of the Burma Oilfields for 1904—1906.*

OILFIELD AND DISTRICT.	1904.	1905.	1906.
	Gallons.	*Gallons.*	Gallons.
Akyab	47,082	53,455	35,423
Kyaukphyu	89,827	60,647	53,429
Yenangyaung, Magwé . . .	73,428,960	85,648,749	89,549,252
Singu, Myingyán	23,677,450	37,541,177	34,843,621
Yenangyát, Pakôkku	18,660,485	18,759,818	13,172,136
Thayetmyo	...	...	400
TOTAL .	115 903,804	142,063,846	137,654,261

The average daily attendances of workers on the Burma oilfields amounted to 1,292 during 1905, and to 1,837 during 1906.

The agreement made between the Burma Oil Company and the producers in the Dutch East Indies has tended to reduce the figures both for imports of foreign kerosene and for exports of Burma oil, although the figures for the former are largely affected by the failure of Russian supplies. Tables 20 and 21 show the variations for the past five years.

TABLE 20.—*Imports of Kerosene during the five years 1902—1906.*

Imported from	1902.	1903.	1904.	1905.	1906.
	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.
Russia	71,995,767	65,434,324	42,256,738	17,205,175	...
United States . .	8,052,364	7,588,569	7,628,275	18,737,577	28,494,794
Borneo	...	1,078,719	6,931,291	7,039,812	1,795,715
Straits Settlements .	1,332,779	1,280,507	8,985,538	12,508,844	8,499,198
Sumatra . . .	285,990	974,981	3,566,619	6,816,991	9,731,405
Other countries . .	291,487	4,479	1,222,397	16,363	6,663
TOTAL .	81,958,387	76,361,579	70,590,858	62,324,762	[illegible]

TABLE 21.—*Exports of Mineral Oil and Paraffin Wax during the five years 1902—1906.*

YEAR.	Mineral oil.	Paraffin wax.
	Gallons	Cwts.
1902	44,002	65,041
1903	747,834	43,206
1904	3,787,677	42,940
1905	2,422,589	63,966
1906	903,545	61,097

Ruby, Sapphire, and Spinel.

The output of ruby, sapphire, and spinel reported by the Burma Ruby Mines Company during the year ending February 28th, 1907, was reported as 326,855 carats, valued at £95,540, against a value of £88,340 returned for the corresponding period 1905-06. Of the total value £93,023 is due to the rubies obtained; the sapphires were valued at £1,132 and spinels at £1,385. The average daily attendances of workers during 1905 amounted to 1,805, and during 1906 to 2,367, in the Ruby Mines District of Burma.

During the year the Kashmir sapphire-mines were again worked and a production of 2,837 carats, valued at £1,327, was reported.

Salt.

There was an unimportant reduction in the quantity of salt produced, the total for 1906 being 1,225,465 tons, against 1,291,137 tons produced in 1905 (table 22).

TABLE 22.—*Provincial Production of Salt during 1904—1906.*

PROVINCE.	1904.	1905.	1906.
	Statute Tons.	Statute Tons.	Statute Tons.
Aden	66,007	97,727	67,535
Bengal	88	3	61
Bombay	430,409	425,090	390,535
Burma	21,387	23,132	29,847
Gwalior State	374	84	249
Madras	356,834	388,646	412,717
Northern India	282,421	342,190	312,559
Sind	13,540	14,265	11,777
TOTAL, Statute Tons	**1,171,060**	**1,291,137**	**1,225.280**
Total, Metric Tons	*1,188,900*	*1,311,856*	*1,244,939*

There was a greater activity in the rock-salt mines of the Punjab, and in addition to an increased output (see table 23), the extension of tunnels has proved the persistence of the two principal seams considerably beyond the area previously known with certainty.

TABLE 23.—*Production of Rock-Salt during 1904—1906.*

—	1904.	1905.	1906.
	Statute Tons.	Statute Tons.	Statute Tons.
Salt Range, Punjab	107,403	94,048	107,194
Kohát	16,664	14,897	13,436
Mandi	4,507	3,571	3,609
TOTAL, Statute Tons	**128,574**	**112,416**	**124,239**
Total, Metric Tons	*130,635*	*114,210*	*126,233*

During 1906 there was an increase in the quantity and value of imported salt, the amount being 512,328 tons and the value £488,127, against averages for the four years 1902—1905 of 454,832 tons and £439,071 respectively.

Saltpetre.

The value of the saltpetre industry is gauged most uniformly by the figures for exports. The returns for the past five years shown in table 24 indicate a gradual rise in the average value, but the industry shows no signs of real expansion.

TABLE 24.—*Exports of Saltpetre during the five years 1902—1906.*

YEAR.	Weight.	*Value.*	Value per cwt.
	Cwts.	£	Shillings.
1902	390,742	*271,867*	13·9
1903	412,593	*290,196*	14·1
1904	390,970	*266,349*	13·6
1905	313,122	*235,723*	15·1
1906	347,251	*270,547*	15·6
Average	**370,936**	**266,936**	**14·5**

The local importance of the saltpetre industry is shown by the returns for labour in Behar where most of the saltpetre is obtained. The returns for 1906 show that 50,469 workers were employed in this industry.

Tin-ore.

The output of tin-ore in South Burma has considerably increased, from 1,495 cwts., valued at £9,783, in 1905, to 1,919 cwts., valued at £13,574, in 1906. A special survey of the tin-mining industry in South Burma is being carried out by an officer of the Geological Survey. The total average daily attendance at the tin mines in the Mergui and Tavoy districts was 145 in 1905 and 141 in 1906.

III.—MINERALS OF GROUP II.

The following notes deal with the minerals for which the returns are only estimated in certain areas with fair accuracy.

Alum.

The production of alum in the Mianwáli district, Punjab, has increased considerably from 7,126 cwts., valued at £2,038, in 1905, to 11,022 cwts., valued at about £4,000, in 1906. In 1904 the production amounted to only 2,580 cwts. The imports of foreign alum were slightly below those returned for 1905, amounting to 69,044 cwts., valued at £20,040.

Amber.

There has been a reduction in the small value reported for the amber raised in the Myitkyina district of Upper Burma, the production for 1906 being valued at £709 although reported as 217 cwts.

Borax.

No borax is produced within Indian territory, but considerable quantities are brought across the frontier from Tibet for consumption in India and for export. The export figures given in table 25 show that there has been no important change in the trade during the past five years.

TABLE 25.—*Exports of Borax during the five years 1902—1906.*

YEAR.	Weight.	*Value.*	Value per cwt.
	Cwts.	£	Shillings.
1902	5,335	*8,028*	30·1
1903	5,674	*7,797*	27·5
1904	4,246	*5,419*	25·5
1905	4,198	*5,246*	25·0
1906	4,220	*5,868*	27·2
Average	**4,738**	**6,472**	**27·2**

Building stone.

The returns for building stone of most general interest are those relating to the quarrying of Vindhyan sandstone in the Mirzapur district, the production during

1906 being reported to amount to 101,745 tons, valued locally at £12,690, against 99,850 tons, valued at £12,727, in 1905. On account of its uniform and fine-grain the Mirzapur sandstone is used largely for ornamental purposes.

Copper.

There is again a small quantity of copper-ore reported as raised in the Mandalay district during 1906, amounting to 587 cwts.; but the returns for value are obviously overstated. Prospecting work has been conducted on the Singbhum copper-bearing belt. At Kodomdia near Kharsawan the zone of copper and iron pyrites, exposed by ancient outcrop workings, has been proved by diamond drilling with a fairly constant dip at depths of 400 and 1,067 feet. Between the levels 392 and 404 feet representing 8 feet thick of the lode, the 12 feet of core obtained contained 5·102 per cent. of copper and 5·8 per cent. sulphur. At a depth of 1,069 feet the cupriferous band was only about one foot in thickness with 1·825 per cent. copper.

Marble.

The production of marble at Makrana in the Jodhpur State was returned as 1,500 tons for 1906, against 1,726 tons in 1905.

Steatite.

The steatite raised in the Minbu district of Burma during 1906 amounted to 200 cwts., valued at £273, against 244 cwts., valued at £341, in 1905.

Tourmaline.

In the Ruby Mines District the tourmaline produced in 1906 amounted to 193 lbs, valued at £1,001, against 161 lbs., valued at £1,500, in 1905. An interesting report has recently been made by Mr. E. C S. George, Deputy Commissioner of the district, on the workings for tourmaline round the small Palaung hamlet of Sanka about a mile east of Maingnin, where operations were carried on by the Chinese, according to local tradition, some 150—200 years ago. Mr. George states that, after the Chinese deserted the area, the Kachins re-started the mines about forty years ago, but the industry was again interrupted until about 1885, when more systematic operations were commenced under Pir Seinda, who contracted to conduct all mining operations until 1895. The Momeit "stone-tract" was afterwards notified by Government and regular licenses were taken up in 1899. During the past three years the amounts recovered by "tourmaline licenses" have been nearly Rs.3,000 (£200) each year. The tourmaline is found in soft, decomposed, granitic veins, which, being covered generally by a thick deposit of

jungle-clad soil, are found rather by accident than through the guidance of any superficial indications. Isolated crystals are found occasionally lying in the red soil, and men with small means find it sometimes profitable, when they have leisure, to search through the soil-cap by digging shallow pits. *Twinlons*, or vertical shafts about 4 or 5 feet square, are also put down on the chance of striking a tourmaline-bearing vein, or *kyaw*, and the owners of these *twinlons* are permitted to extend their workings underground to a radius of five fathoms from the centre of each shaft. Some of the workings extend to depths of about 100 feet, which appears to be about the limit of the miners' engineering skill. The tourmaline found is sorted into three classes: (1) *Ahtet yay*, the best light-pink rubellite, of which there are two kinds, *hteik ti*, showing well-developed basal planes, and *bé yan*, crystals terminated by rhombohedral faces, or with only a small development of the basal plane. (2) *Akka*, of a darker colour with the lower part of the crystals brown or black in colour. (3) *Sinsi* or *Arnyi*, all fragmentary crystals of any colour which are imperfect, or of a small size less than about an inch. The *sinsi* is given without charge to the buyer of the lots of the two better kinds. The best kind, *Ahtet yay*, may bring as much as Rs. 1,200 to Rs. 1,500 a viss (3·65 lbs.). The *Myaw* system, or exposure of the veins on the hill-side by hydraulic action, has also been attempted at two localities with uncertain results: this work is limited to the "rains" and is handicapped by the cost of leading the water-channels for long distances. All locally made purchases are effected by brokers, usually Shans or Shan Burmans. They in turn sell at Mandalay to purchasers for the Chinese market.

IV.—MINERAL CONCESSIONS GRANTED.

TABLE 26.—*Statement of Mineral Concessions made in Government lands during the year 1906.*

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
BALUCHISTAN.	Loralai	(1) Messrs. Abdulla Asghar Ali & Co.	Coal	Mining lease.	20	1st July 1906.	30 years.
	Quetta-Pishin.	(2) Messrs. Isaji & Sons	Do.	Prospecting license.	Plot A 286·501 acres, Plot B 104·6 acres, Sor Range, between miles 2 and 7.	5th December 1906.	1 year.
BENGAL.	Gaya	(3) Jhaman Singh *alias* Jang Bahadur Singh.	Mica	Conversion of prospecting license to mining lease	18 (about)	The lease has not yet been executed.	10 years.
	Hazaribagh	(4) Mr. E. Lane	Do.	Prospecting license.	120	12th November 1906.	1 year.
	Do.	(5) Mr. K. E. Heyneman.	Do.	Do.	280	Do.	Do.
	Moharbhanj	(6) Messrs. B. Barooah and Patrick Gow.	Gold	Do.	23,040	10th July 1906.	2 years.
	Manbhum	(7) Sita Ram Marwari and others.	Coal	Mining lease.	80·561	28th August 1906.	30 years.
	Singbhum	(8) Messrs. Hoare Miller & Co., Calcutta.	All sorts of minerals.	Exploring license.	Area between the parallels of lat. 20° 11′ N. & 22° 21′ N. & between the meridians of long. 85° 15′ E. & 85° 28′ E.	7th September 1906.	1 year.
	Sonthal Parganas.	(9) Maghu Mean	Coal	Mining lease.	·137	1st October 1906.	2 years.
BOMBAY.	Dharwar	(10) Sangli Gold Mines, Ld.	Gold	Do.	275·8	2nd January 1906.	30 years.
	Do.	(11) Do. do.	Do.	Do.	588·27	Do.	Do.
	Do.	(12) Mr. C. H. B. Forbes.	Do.	Prospecting license.	1,638·3	27th January 1906.	1 year.

PROVINCE.	District.	Grantee	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
BOMBAY—*contd.*	Dharwar	(13) The Dharwar Gold Mines, Ld.	Gold	Mining lease.	163·28	2nd April 1906.	30 years.
	Do.	(14) Mr. R. O. Ahlers (Agent for the Gold Fields of Dharwar).	Do.	Do.	589·22	13th June 1906.	Do.
	Panch Mahals.	(15) F. A. H. East, Agent, Shivrajpur Syndicate, Ld., Bombay.	Manganese-ore.	Prospecting license.	401	26th October 1906.	1 year.
	Do.	(16) Do. do.	Mica.	Exploring license.	150	Do.	Do.
BURMA.	Bassein	(17) Maung Po Mya	Coal	Prospecting license.	3,200	1st September 1906.	Do.
	Bhamo	(18) Maung Law Ku	Precious stones.	Exploring license.	16,000	3rd January 1906.	Do.
	Do.	(19) Htam Saing	Do.	Do.	Not reported.	28th July 1906.	Do.
	Katha	(20) Mr. J. M. Minus	Gold	Prospecting license.	605·44	20th January 1906.	Do.
	Do.	(21) Mr. J. A. Manyon	Coal	Do.	1,350·40	16th May 1906.	Do.
	Do.	(22) Maung San Ye	Gold	Do.	11·20	17th September 1906.	Do.
	Do.	(23) M. Baksh	Do.	Exploring license.	Not reported.	12th November 1906.	Do.
	Do.	(24) Mr. J. A. Manyon	Copper, lead, and associated ores	Do.	2,880	21st December 1906.	Do.
	Magwé	(25) Messrs. J. S. Jamal Bros. & Co.	Petroleum	Prospecting license.	1,920	1st February 1906.	Do.
	Do.	(26) Do. do.	Do.	Do.	640	Do.	Do.
	Do.	(27) Do. do.	Do.	Do.	640	28th March 1906.	Do.
	Do.	(28) Messrs. Finlay, Fleming & Co.	Do	Mining lease.	Blocks C, B_2, 1*, 2*, and part of Beme reserve at Yenangyaung.	1st May 1906.	30 years.
	Do.	(29) Do. do., Agents for the Burma Oil Co., Ld.	Do.	Prospecting license (renewal).	1,280	11th October 1906.	1 year.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
BURMA—*contd.*	Mergui .	(30) Mr. Louis Joel .	Tin . .	Prospecting license.	307·56	19th April 1906.	1 year.
	Do. .	(31) Mr. Charles Kitchin.	Do. . .	Do. .	640	25th August 1906.	Do.
	Myingyan .	(32) Messrs. Finlay, Fleming & Co., Agents for the Burma Oil Co., Ld.	Petroleum .	Do. .	85	19th January 1906.	Do.
	Do. .	(33) Do. do. .	Do. .	Do. .	1,280	15th September 1905.	Do.
	Do. .	(34) Do. do. .	Do. .	Do. .	2,560	26th July 1906.	Do.
	Do. .	(35) Do. do. .	Do. .	Do. .	3,840	10th August 1906.	Do.
	Do. .	(36) Do. do. .	Do. .	Do. .	21,440	1st May 1906.	Do.
	Do. .	(37) Messrs. Geo. Gillespie & Co., Agents for the Rangoon Oil Co.	Do.	Prospecting license (renewal).	640	10th May 1906.	Do.
	Myitkyina .	(38) Messrs. Diekmann Bros. & Co.	Gold .	Exploring license.	20 miles of the Uyu river from Kunhe to Kama, a village above Haungpa.	10th December 1906.	Do.
	N. Shan States.	(39) Mr. F. Dietzsch, on behalf of the Burma Prospecting Syndicate, Ld.	Do. . .	Do. .	98,470·40	24th March 1906.	Do.
	Do. .	(40) Mr. N. Samwell .	Silver, lead ores, and the associated minerals combined therewith.	Prospecting license.	3,200	24th September 1906.	Do.
	Pakôkku	(41) Mr. H. W. Watts	Coal and petroleum.	Do. .	2,560	10th February 1906.	Do.
	Do. .	(42) Messrs. Ko Ba Oh & Co.	Petroleum (renewal).	Do. .	1,280	13th March 1906.	Do.
	Do. .	(43) Messrs. Finlay, Fleming & Co.	Petroleum .	Do. .	640	11th April 1906.	Do.
	Do. .	(44) Do. do. .	Do. .	Do. .	640	Do. .	Do.
	Do. .	(45) Do. do. .	Do. .	Do. .	1,280	12th June 1906.	Do.

Province.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
BURMA—*contd.*	Pakokku .	(46) Messrs. Ko Ba Oh & Co.	Petroleum .	Prospecting license.	102	6th July 1906.	1 year.
	Do. .	(47) Messrs. A. S. Jamal Bros. & Co.	Do. .	Do. .	2,483	13th December 1906.	Do.
	Do. .	(48) Captain Waymouth, on behalf of Irrawaddy Flotilla Co.	Petroleum and coal.	Exploring license.	30,720	17th December 1906.	Do.
	Prome .	(49) Messrs. Finlay, Fleming & Co., Agents for the Burma Oil Co., Ld.	Petroleum	Prospecting license.	3,520	8th January 1906.	Do.
	Sagaing .	(50) Mr. C. Findlay .	Copper .	Do. .	426·66	29th May 1906.	Do.
	Shwebo .	(51) Messrs S. A. Mower, G. S. Clifford, E. S. Attia, and Mrs. Mary Vertannes	Gold, silver, and rubies.	Do. .	205·45	1st July 1906.	Do.
	S. Shan States.	(52) Maung Kyaw Zan, on behalf of Colonial Trading Co.	Mica .	Exploring license.	1,051,520	16th November 1906.	Do.
	Do. .	(53) Tamon of Heho Saya Kyi of Yaungbwe.	Silver and lead.	Prospecting license.	18	20th December 1906.	Do.
	Do. .	(54) Maung E. Maung and Moulvi Hyder Ali.	Coal .	Do. .	3,200	26th April 1906.	Do.
	Do. .	(55) Maung Thu Daw	Precious stones.	Exploring license.	252,800	27th April 1906.	Do.
	Do. .	(56) Burma Mining Syndicate.	Gold .	Prospecting license.	8·25	9th August 1906.	Do.
	Tavoy .	(57) Mr. A. G. Meinhold, Manager, Diekmann Bros.	Gold, silver, tin, copper, coal, plumbago, and precious stones.	Prospecting license (renewal).	3,744	1st December 1906.	Do.
	Do. .	(58) Mr. T. Fowle .	Do. .	Prospecting license.	32,000	26th January 1906.	Do.
	Do. .	(59) Messrs. Diekmann Bros. & Co., Ld., and Lieut.-Colonel Foss.	Gold and tin	Prospecting license (renewal of Mr. Rickett's license subsequently assigned to Col. Foss).	3,744	1st December 1905.	Do.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
BURMA—*concld.*	Tavoy	(60) Mr. R. Gilfillan, on behalf of Golden Stream Syndicate.	Gold, silver, tin, copper, coal, plumbago, and precious stones.	Prospecting license (renewal).	224,000	20th September 1905.	1 year.
	Thayetmyo	(61) Messrs. A. S. Jamal Bros. & Co.	Petroleum	Prospecting license.	640	12th January 1906.	Do.
	Do.	(62) Messrs. Finlay, Fleming & Co., Agents for the Burma Oil Co., Ld.	Do.	Do.	5,760	16th January 1906.	Do.
	Do.	(63) Messrs. A. S. Jamal Bros. & Co.	Do.	Do.	378	12th January 1906.	Do.
	Toungoo	(64) Messrs. T. F. Francis, Agent for Mr. C. E. Brown.	Silver, lead, and other metals.	Prospecting license.	3,200	30th April 1906.	Do.
	Upper Chindwin.	(65) Messrs. A. S. Jamal Bros. & Co.	Petroleum	Do.	6,400	17th March 1906.	Do.
	Yamèthin	(66) Lin Chin Tsong	Gold and tin	Do.	5,120	13th October 1906.	Do.
CENTRAL PROVINCES.	Balaghat	(67) Mr. P. Gow, Calcutta.	Bauxite	Do.	1,189	14th March 1906.	Do.
	Do.	(68) Messrs. C. D. Stewart & Co., Calcutta.	Do.	Do.	4,681	22nd February 1906.	Do.
	Do.	(69) The Indian Manganese Company.	Manganese	Do.	310	Do.	Do.
	Do.	(70) Messrs. Dutt, Burn & Co., Jubbulpore.	Do.	Do.	806	29th September 1906.	Do.
	Do.	(71) Mr. P. Gow, Calcutta.	Bauxite	Do.	6,398	19th September 1906.	Do.
	Do.	(72) Messrs. P. C. Dutt, Burn & Co., Jubbulpore.	Manganese and iron.	Exploring license.	5,523	16th August 1906.	Do.
	Do.	(73) Do. do.	Do.	Do.	58,380	Do.	Do.
	Do.	(74) Mr. J. Kellerschon, Nagpore.	Manganese	Do.	4,894	13th August 1906.	Do.
	Do.	(75) Do. do.	Do.	Do.	755	22nd August 1906.	Do.
	Do.	(76) Messrs. Dutt, Burn & Co., Jubbulpore.	Iron and manganese.	Prospecting license.	345	22nd September 1906.	Do.
	Do.	(77) The Central Provinces Prospecting Syndicate, Kamptee.	Manganese	Mining lease; extension of the Bharveli manganese mines.	8	13th July 1906.	30 years

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
CENTRAL PROVINCES—*contd.*	Balaghat .	(78) Mr. D. Laxminarayan, Kamptee.	Manganese	Prospecting license.	236	4th July 1906.	1 year.
	Do .	(79) Do. do. .	Do. .	Do. .	36	2nd May 1906.	Do.
	Do. .	(80) Do. do. .	Do. .	Do. .	451	4th May 1906.	Do.
	Do. .	(81) Do. do. .	Do. .	Do. .	2,716	2nd May 1906.	Do.
	Do. .	(82) Central Provinces Prospecting Syndicate.	Do. .	Do. .	385	4th September 1906.	Do.
	Do. .	(83) Rai Sahib Mathura Prosad and Motilal.	Do. .	Do. .	118	6th December 1906.	Do.
	Do. .	(84) Diwan Bahadur Kastur Chand Daga.	Do. .	Do. .	660	17th December 1906.	Do.
	Do. .	(85) Do. do. .	Do. .	Do. .	1,160	Do. .	Do.
	Betul .	(86) Raja Gokuldas, Rai Bahadur Ballabhdas, Jubbulpore.	Coal and mineral ore.	Exploring license.	11,897	28th August 1906.	Do.
	Do. .	(87) Hon'ble Mr. Vithaldas Damoodhar Thakersay, J. P.	Coal and petroleum.	Prospecting license.	37,142	15th December 1906.	Do.
	Bhandara .	(88) Mr. D. Laxminarayan.	Manganese	Do. .	85	12th November 1906.	Do.
	Do. .	(89) Rai Sahib Mathura Prosad and Motilal.	Do. .	Do. .	30	Do. .	Do.
	Do. .	(90) Mr. M. Trikumdas Cooverji Bhoja.	Manganese, iron-ore, and galena.	Do. .	457	20th December 1906.	Do.
	Do. .	(91) Mr. E. G. Beckett	Manganese	Do. .	151	27th November 1906.	Do.
	Do .	(92) Rai Sahib Mathura Prosad and Motilal.	Do. .	Do. .	44	1st December 1906.	Do.
	Do. .	(93) Mr. G. M. Prichard.	Do. .	Do. .	1,828	20th December 1906.	Do.
	Do.	(94) Do. do. .	Do. .	Do. .	939	15th November 1906.	Do.
	Do. .	(95) Rai Sahib Mathura Prosad and Motilal.	Do. .	Do. .	99	24th November 1906.	Do.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
CENTRAL PROVINCES—*contd.*	Bhandara .	(96) Diwan Bahadur Kastur Chand Daga.	Manganese	Exploring license.	1,476	18th December 1906.	1 year.
	Do. .	(97) Mr. D. Laxminarayan, Kamptee.	Do. .	Prospecting license.	20	21st April 1906.	Do.
	Do. .	(98) Do. do. .	Do. .	Do. .	274	Do. .	Do.
	Do. .	(99) Do. do. .	Do. .	Do. .	301	11th June 1906.	Do.
	Do. .	(100) Mr. R. H. Richardson, Tumsar.	Do. .	Exploring license.	807	Do. .	Do.
	Do. .	(101) Mr. G. M. Prichard, Kamptee.	Do. .	Do. .	2,952	18th June 1906.	Do.
	Do. .	(102) Central India Mining Co., Ld., Kamptee.	Do. .	Prospecting license.	1,111	30th April 1906.	Do.
	Do. .	(103) Do do. .	Do. .	Do. .	68	Do. .	Do.
	Do. .	(104) Do. do. .	Do.	Do. .	723	Do. .	Do
	Do. .	(105) Mr. D. Laxminarayan, Kamptee.	Do. .	Do. .	25	21st April 1906.	Do.
	Do. .	(106) Do. do. .	Do. .	Do. .	44	2nd January 1906.	Do.
	Do. .	(107) Rai Sahib Mathura Prosad and Motilal, Chhindwara.	Do. .	Do. .	474	18th August 1906.	Do.
	Chanda . .	(108) Messrs. Tata & Sons.	Iron . .	Mining lease	160	1st December 1906.	30 years.
	Chhindwara	(109) Ratanchand Kesrichand.	Coal . .	Prospecting license.	2,262	17th January 1906.	1 year.
	Jubbulpore	(110) Mr. Srish Chandra Roy Chowdhri, Pleader.	Gold, silver, copper, and lead.	Exploring license.	8,487	15th January 1906.	Do.
	Do. .	(111) P. C. Dutt, Esq., Barrister-at-Law.	Gold, silver, copper, lead, barytes, iron, manganese, and tin.	Do. .	6,881	Do. .	Do.
	Do. .	(112) Messrs. H. F. Cook & Son, Katni.	Aluminium, coal, iron-ore.	Do. .	2,946	29th September 1906.	Do.
	Do. .	(113) P. C. Dutt, Esq., Barrister-at-Law.	Bauxite .	Prospecting license.	219	21st June 1906.	Do.
	Do. .	(114) Mr. Srish Chandra Roy Chowdhri.	Gold, silver, copper, and lead.	Do. .	35	9th April 1906.	Do.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
CENTRAL PROVINCES—contd.	Jubbulpore	(115) The Jubbulpore Prospecting Syndicate.	Iron, manganese, and copper.	Exploring license.	4,588	1st June 1906.	1 year.
	Do.	(116) Do. do.	Gold, silver, copper, lead, antimony, arsenic, barytes, dolomite, limestone, zinc, and tin.	Prospecting license (renewal).	3,791	22nd February 1906.	Do.
	Do.	(117) Messrs. Burn & Co., Calcutta.	Gold, silver, copper, iron, zinc, tin, and coal.	Exploring license.	5,993	4th October 1906.	Do.
	Do.	(118) Messrs. H. F. Cook & Sons.	Gold, silver, copper, platinum, zinc, tin, lead, nickel, mercury, manganese, and diamond.	Do.	30,810	13th November 1906.	Do.
	Do.	(119) Do. do.	Gold, silver, zinc, lead, titanium, tungsten, tin, uranium, and platinum.	Do.	8,442	5th November 1906.	Do.
	Nagpur	(120) Central Provinces Prospecting Syndicate, Kamptee.	Manganese	Mining lease	45	24th May 1906.	30 years.
	Do.	(121) Mr. Trikumdas Cooverji Bhoja, Calcutta.	Do.	Prospecting license.	50	2nd May 1906.	1 year.
	Do.	(122) Mr. E. G. Beckett, Kamptee.	Do.	Do.	101	13th June 1906.	Do.
	Do.	(123) Mr. G. M. Prichard, Kamptee.	Do.	Exploring license.	30	10th September 1906.	Do.
	Do.	(124) Do. do.	Do.	Do.	3,207	Do.	Do.
	Do.	(125) Mr. Trikumdas Cooverji Bhoja, Calcutta.	Do.	Prospecting license.	794	20th July 1906.	Do.
	Do.	(126) Central Provinces Prospecting Syndicate, Kamptee.	Do.	Mining lease.	17	21st August 1906.	30 years
	Do.	(127) Do. do.	Do.	Do.	12	7th July 1906.	Do.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
CENTRAL PROVINCES—*concld.*	Nagpur .	(128) Mr. D. Laxminarayan, Kamptee.	Manganese	Prospecting license.	13	15th August 1906.	1 year.
	Do. .	(129) The Central India Mining Co., Ld.	Do. .	Do. .	103	7th February 1906.	Do.
	Do. .	(130) Do. do. .	Do. .	Mining lease .	170	Do. .	30 years.
	Do. .	(131) Do. do. .	Manganese and copper.	Prospecting license.	4,066	28th March 1906.	1 year.
	Do. .	(132) Mr. D. Laxminarayan, Kamptee.	Coal . .	Do. .	1,241	26th March 1906.	Do.
	Do. .	(133) Do. do. .	Manganese	Do. .	189	Do. .	Do.
	Do. .	(134) Do. do. .	Do. .	Do. .	53	27th June 1906.	Do.
	Do. .	(135) Do. do. .	Do. .	Do. .	94	21st December 1906.	Do.
	Do. .	(136) Mr. J. Kellerschon.	Do. .	Exploring license.	388	21st November 1906.	Do.
	Do. .	(137) Do. do. .	Do. .	Do. .	388	Do. .	Do.
	Do. .	(138) Do. do. .	Do. .	Do. .	859	Do. .	Do.
	Do. .	(139) Do. do. .	Do. .	Do. .	959	Do. .	Do.
	Saugor .	(140) Messrs. Kali Prasanna Mukerji and Bhagwan Das Sirvaya.	Mica, corundum, and dolomite.	Do. .	8,563	29th September 1906.	Do.
	Do. .	(141) Do. do. .	Iron-ore and other ores.	Do. .	1,130	30th October 1906.	Do.
EASTERN BENGAL AND ASSAM.	Cachar .	(142) Mr. W. Gordon Stoker.	Mineral oil and coal.	Prospecting license.	362,592	......	...
	Chittagong	(143) Messrs. Turner, Morrison & Co., Calcutta.	Coal, oil, gold or silver, iron, copper, tin, or other metals and other precious stones.	Do. .	11,520	10th July 1906.	1 year.
MADRAS.	Anantapur.	(144) Mr. H. P. Gibbs	Gold .	Do. .	4,095	25th September 1906.	Do.
	Bellary .	(145) Mr. E. D. Puzey	Do. . .	Do. .	634·87	31st July 1906.	Do.
	Do. .	(146) Mr. C. Jambon .	Minerals .	Exploring license.	4,248·96	4th August 1906.	Do.
	Do. .	(147) Mr. C. J. Greengrass.	Manganese	Prospecting license.	1,594·95	4th September 1906.	Do.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
MADRAS—*contd.*	Bellary .	(148) Mr. C. Jambon .	Manganese	Prospecting license.	2,270·81	7th September 1906.	1 year.
	Do. .	(149) Mr. W. T. Hamilton-Holmes.	Gold .	Do. .	1,920	19th December 1905.	Do.
	Do. .	(150) R. Srinivasa Rao Nayudu.	Manganese	Do. .	1,472	11th October 1906.	Do.
	Do. .	(151) F. E. Dum .	Do. .	Do. .	319	28th November 1906.	Do.
	Coimbatore	(152) Govindjee Odajee Sait.	Corundum.	Mining in patta land.	8·28	23rd November 1906.	20 years.
	Kistna .	(153) The Southern India Coal Mining Syndicate, Ld., Madras.	Coal and other minerals.	Exploring license.	184,445·27	13th November 1906.	1 year.
	Do. .	(154) P. Venkatarama Nayudu.	Mica. .	Prospecting license.	17·50	13th October 1906.	Do.
	Nellore .	(155) D. Venkata Rao	Manganese	Exploring license.	Area not fixed.	12th September 1906.	Do.
	Do. .	(156) K. Panchala Reddi.	Mica .	Prospecting license.	25·68	17th December 1906.	Do.
	Do. .	(157) K. Kothandarami Reddi.	Do. . .	Do. .	20	Do. .	Do.
	Do. .	(158) R. Lakshminarasa Reddi.	Do. . .	Do. .	37·45	Do. .	Do.
	Do. .	(159) Do. do. .	Do. . .	Do. .	30·80	19th December 1906.	Do.
	Do. .	(160) Murlidar Chadik	Do. . .	Mining in patta land.	5	25th June 1906.	Do.
	Do. .	(161) K. Kodandarami Reddi.	Do. . .	Prospecting license.	19·16	13th September 1906.	Do.
	Do. .	(162) Y. Kelappa Chetti and S. Chinnachenchu Nayudu.	Do. . .	Mining lease extension.	185·98	14th August 1906.	30 years.
	Do .	(163) I. Pattabhirami Reddi.	Do. . .	Prospecting license.	26·73	24th October 1906.	1 year.
	Do. .	(164) R. Lakshminarasa Reddi.	Do. . .	Do. .	10·20	24th October 1906.	Do.
	Do. .	(165) T. Venkata Reddi	Do. . .	Do. .	19·90	20th October 1906.	Do.
	Do .	(166) Do. do. .	Do. . .	Do. .	11·60	22nd October 1906.	Do.
	Do. .	(167) Do. do. .	Do. . .	Do. .	20	Do. .	Do.
	Do.	(168) Y. Kalappa Chetti and S. Chinnachenchu Nayudu.	Do. . .	Mining lease.	14·96	28th August 1905.	30 years.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
MADRAS—*contd.*	Nellore .	(169) M. Devarajulu Nayudu.	Mica .	Mining lease.	23	18th September 1905.	30 years.
	Do. .	(170) A Venkatachala Mudallyar.	Do. . .	Do. .	13·24	5th August 1905.	Do.
	Do.	(171) Messrs. Hali Muhammad Badsha Sahib & Co.	Do. . .	Do. .	9·65	26th September 1905.	Do.
	Do. .	(172) P. Penchala Reddi.	Do . .	Do. .	57·62	7th October 1905.	3 years.
	Do. .	(173) K. Appayya Chetti.	Do. . .	Do. .	218·60	13th December 1905.	30 years.
	Do. .	(174) R. Rangaswami Row.	Do. . .	Do. .	100·20	22nd September 1905.	3 years.
	Do. .	(175) C. H. Jefferson	Do. . .	Mining in patta land.	5·38	30th November 1905.	20 years.
	Do. .	(176) Y. Venkatasubbia Chetti.	Do. . .	Do. .	32	7th February 1906.	Do.
	Do. .	(177) I. Pattabhirami Reddi.	Do. . .	Prospecting license.	39·32	24th February 1906.	1 year.
	Do. .	(178) I. Venkatarama Nayudu.	Do. . .	Do. .	36·33	19th February 1906.	Do.
	Do. .	(179) I. Pattabhirami Reddi.	Do. . .	Do. .	11·43	18th January 1906.	Do.
	Do. .	(180) Do. do. .	Do. . .	Do. .	18·52	24th February 1906.	Do.
	Do. .	(181) T. Venkata Reddi.	Do. . .	Do. .	12·31	2nd February 1906.	Do.
	Do. .	(182) I. Pattabhirami Reddi.	Do. . .	Do. .	23·79	23rd August 1906.	Do.
	Do. .	(183) Virjiyamma .	Do. . .	Do. .	96·40	Do. .	Do.
	Do. .	(184) P. Venkatarama Nayudu.	Do . .	Mining lease.	46·14	5th January 1906.	30 years.
	Do. .	(185) T. Venkata Reddi.	Do. . .	Exploring license.	Not fixed	4th August 1906.	1 year.
	Do. .	(186) Do. do. .	Do. . .	Prospecting license.	19·97	2nd February 1906.	Do.
	Do. .	(187) Do. do. .	Do. . .	Do. .	10·47	Do. .	Do.
	Do. .	(188) R. V. Kuppuswami Aiyar.	Do. . .	Do. .	18·85	24th January 1906.	Do.
	Do. .	(189) T. Venkata Reddi.	Do. . .	Do. .	12·21	2nd February 1906.	Do.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
MADRAS—*contd.*	Nellore	(190) K. Adinarayana Reddi.	Mica	Exploring license.	All unoccupied lands in the Gudur and Rampur taluks.	24th January 1906.	1 year.
	Do.	(191) Verji Jumma	Do.	Prospecting license.	66·70	24th March 1906.	Do.
	Do.	(192) I. Pattabhirami Reddi.	Do.	Mining lease.	109·47	Do.	3 years.
	Do.	(193) P. Pitchi Reddi	Do.	Mining in patta land.	2·30	6th May 1906.	20 years.
	Do.	(194) K. Linga Reddi	Do.	Prospecting license.	34·80	23rd July 1906.	1 year.
	Do.	(195) I. Pattabhirami Reddi.	Do.	Do.	19·80	19th September 1906.	Do.
	Do.	(196) G. Ramaswami Nayudu & Sons.	Do.	Mining lease.	20·70	18th May 1906.	30 years.
	Do.	(197) R. V. Kuppuswami Aiyar.	Do.	Do.	13·38	10th November 1905.	Do.
	Do.	(198) V. Narayana Chetti.	Do.	Do.	20·55	24th October 1905.	3 years.
	Do.	(199) Haji Muhammad Badsha Sahib & Co.	Do.	Do.	187·62	15th January 1906.	30 years.
	Do.	(200) Do. do.	Do.	Do.	133·70	14th March 1906.	Do.
	Do.	(201) A. Subba Nayudu	Do.	Do.	81·26	16th March 1906.	Do.
	Do.	(202) Do. do.	Do.	Do.	271·31	Do.	Do.
	Do.	(203) Muhammad Asaduddin Ahmed and Muhammad Ziuddin Ahmed.	Do.	Do.	15·87	1st March 1906.	8 years.
	Do.	(204) Haji Muhammad Badsha Sahib & Co.	Do.	Do.	122·60	14th December 1905.	30 years.
	Do.	(205) A. Subba Nayudu	Do.	Do.	98·26	16th March 1906.	Do.
	Do.	(206) Do. do.	Do	Do.	156	31st March 1906.	Do.
	Do.	(207) Do. do.	Do.	Do.	163·8	Do.	Do.
	Do.	(208) Do. do.	Do.	Do.	121·70	3rd March 1906.	Do.
	Do.	(209) R. V. Kuppuswami Aiyar.	Do.	Do.	26·42	15th March 1906.	Do.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
MADRAS—*contd.*	Nellore .	(210) G. Ramaswami Nayudu & Sons.	Mica .	Mining lease.	25·90	19th April 1906.	30 years.
	Do. .	(211) B. Pattabhirami Reddi.	Do. . .	Do. .	85·90	24th February 1906.	Do.
	Do. .	(212) T. Venkata Reddi	Do. . .	Do. .	66·80	9th March 1906.	3 years.
	Do. .	(213) Haji Muhammad Badsha Sahib & Co.	Do. . .	Do. .	22·55	24th February 1906.	30 years.
	Do. .	(214) R. V. Kuppuswami Aiyar.	Do. . .	Do. .	101·13	1st December 1905.	Do.
	Do. .	(215) K. Adinarayana Reddi and I. Pattabhirami Reddi	Do. . .	Do. .	76·12	9th February 1906.	3 years.
	Do. .	(216) K. Adinarayana Reddi.	Do. . .	Do. .	12·34	5th March 1906.	Do.
	Do. .	(217) Balarami Reddi	Do. . .	Do. .	47	16th April 1906.	Do.
	Do. .	(218) T. Sitarami Reddi	Do. . .	Do. .	61·20	17th April 1906.	Do.
	Do. .	(219) P. Kodandarami Reddi and Ramalinga Reddi.	Do. . .	Do. .	35·60	24th April 1906.	30 years.
	Do. .	(220) A. Venkitachela Mudaliyar.	Do . .	Do. .	71·70	11th May 1906.	Do.
	Do. .	(221) J. Pattabhirami Reddi.	Do. .	Prospecting license.	12·81	28th May 1906.	1 year.
	Do. .	(222) Muhammad Khairuddin.	Do. . .	Do. .	12·30	6th April 1906.	Do.
	Do. .	(223) B. Pattabhirami Reddi.	Do. . .	Do. .	28·10	29th May 1906.	Do.
	Do. .	(224) C. H. Jefferson .	Do. . .	Do. .	20	22nd May 1906.	Do.
	Do. .	(225) R. Lakshminarasai Reddi.	Do. . .	Do. .	25·60	13th June 1906.	Do.
	Do. .	(226) A. Venkatarama Aiyar and T. Chinnaswam Iyer.	Do. . .	Do. .	48·10	30th May 1906.	3 years.
	Do. .	(227) V. Venkatasubbiah Chetti.	Do. . .	Mining in patta land.	4·50	8th June 1906.	20 years.
	Do. .	(228) K. Adinarayana Reddi.	Do. . .	Mining lease	45·34	10th May 1906.	3 years.
	Do. .	(229) R. V. Kuppuswami Iyer.	Do. . .	Prospecting license.	19	17th May 1906.	1 year.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
MADRAS—*concld.*	Nellore	(230) Kundan Dass	Mica	Mining in patta land.	1·60	30th May 1906.	20 years
	Do.	(231) K. Krishnaswami Mudaliyar.	Do.	Do.	1·70	28th May 1906.	Do.
	Do.	(232) T. Venkata Reddi	Do.	Prospecting license.	11·52	15th June 1906.	1 year.
	Do.	(233) R. Rangaswami Row.	Do.	Do.	19·75	22nd May 1906.	Do.
	Do.	(234) R. V. Kuppuswami Iyer.	Do.	Do.	24·68	17th May 1906.	Do.
	Do.	(235) Do. do.	Do.	Mining in patta land.	5	19th May 1906.	20 years.
	Do.	(236) D. Venkata Row	Do.	Prospecting license.	13·50	26th June 1906.	1 year.
	Do.	(237) Haji Muhammad Badsha Sahib & Co.	Do.	Mining lease.	3	26th January 1906.	5 years.
	Do.	(238) P. Subarami Reddi.	Do.	Do.	48	16th July 1906.	30 years
	Nilgiris	(239) Mr. F. W. F. Fletcher.	Gold	Prospecting license.	103·85	29th August 1906.	2 years.
	Salem	(240) Govindji Odoji Sait.	Corundum	Do.	1,566·61	1st April 1906.	1 year.
	Do.	(241) The Morgan Crucible Co., Ld., Trivandrum.	Magnesite	Do.	358·44	25th September 1905.	Do.
	Vizagapatam.	(242) Messrs. P. Macfadyen & Co.	Minerals of every description and mineral oil.	Exploring license.	254,048	4th August 1906.	Do
	Do.	(243) Mr Tom Caplen, Manager, Vizianagram Mining Co.	Minerals and mineral ore.	Do.	254,048	28th November 1906	Do.
PUNJAB.	Attock	(244) S. Mehdi Shah of Mirza.	Coal	Prospecting license.	717½	7th March 1906.	Do
	Jhelum	(245) Rai Sahib Rocha Ram & Sons.	Do.	Do.	233	21st June 1906.	Do.
	Do.	(246) Do. do.	Do.	Do.	495	Do.	Do.
	Mianwáli	(247) Rai Bahadur Anup Singh & Co., represented by Sardar Lakshman Singh.	Do.	Mining lease.	2,876	Lease under execution.	15 years.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
PUNJAB—*contd.*	Pind Dadan Khan.	(248) Punjab Coal Co.	Coal . .	Prospecting license.	152	22nd April 1904.	1 year. Renewed till 21st April 1907.
	Do. .	(249) Rai Sahib Rocha Ram & Sons.	Do. . .	Do. .	256	17th November 1906.	1 year.
	Do. .	(250) Pandit Bhola Nath.	Do. . .	Do. .	120	21st December 1906.	Do.
	Do. .	(251) Do. do. .	Do. . .	Do. .	295	Do. .	Do.
	Shahpur .	(252) Rai Sahib Rocha Ram & Sons.	Do. . .	Do. .	833	23rd June 1906.	Do.

Summary.

PROVINCES.	Prospecting licenses.	Exploring licenses.	Mining leases.	Total of each Province.
Baluchistan	1	...	1	**2**
Bengal	3	1	3	**7**
Bombay	2	1	4	**7**
Burma	40	9	1	**50**
Central Provinces	46	23	6	**75**
Eastern Bengal and Assam	2	...	...	**2**
Madras	45	7	48	**100**
Punjab	8	...	1	**9**
Total for each kind and Grand Total, 1906 .	**147**	**41**	**64**	**252**
Totals for 1905 .	**115**	**44**	**30**	**189**

CLASSIFICATION OF LICENSES AND LEASES.

TABLE 27.—*Prospecting and Mining Licenses granted in Baluchistan during 1905 and 1906.*

DISTRICT.	1905. No.	1905. Area. Acres.	1905. Mineral.	1906. No.	1906. Area. Acres.	1906. Mineral.
			Prospecting Licenses.			
Loralai . .	1	20	Coal .	...	...	...
Quetta-Pishin	...	...	...	1	391·101	Coal.
TOTAL .	1	...	...	1	...	...
			Mining Leases.			
Loralai . .	...	...	...	1	20	Coal.
Quetta-Pishin	2	120	Chromite and coal.	...	...	...
Zhob . .	2	160	Chromite .	...	...	...
TOTAL .	4	...	...	1	...	...

TABLE 28.—*Prospecting and Mining Licenses granted in Bengal during 1905 and 1906.*

DISTRICT.	1905. No.	1905. Area. Acres.	1905. Mineral.	1906. No.	1906. Area. Acres.	1906. Mineral.
			Prospecting Licenses.			
Darjeeling .	1	510	Any mineral, especially copper ores.	...	...	...
Hazaribagh .	...	...	...	2	400	Mica.
Moharbhanj	1	12,800	Iron-ores .	1	23,040	Gold.
TOTAL .	2	...	...	3	...	...

TABLE 28.—*Prospecting and Mining Licenses granted in Bengal during 1905 and 1906*—contd.

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Mining Leases.						
Gaya . .	...	...	...	1	18	Mica.
Manbhum .	...	...	...	1	80·561	Coal.
Sonthal Parganas.	...	...	...	1	·137	Do.
TOTAL .	0	...	...	3	...	...

TABLE 29.—*Prospecting and Mining Licenses granted during 1905 and 1905.*

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Belgaum .	2	22,997·12	Manganese	...	...	...
Dharwar .	7	5,177	Gold and manganese.	1	1,638·3	Gold.
Kanard .	1	4,992	Manganese	...	...	...
Panch Mahals	1	706·19	Do.	1	401	Manganese.
Satara . .	1	1,280	Bauxite and other minerals.	...	...	...
TOTAL .	12	...	...	2	...	...
Mining Leases.						
Belgaum .	1	...	Coal and manganese.	...	...	...
Dharwar .	...	...	...	4	1,616·37	Gold.
TOTAL .	1	...	...	4	...	...

TABLE 30.—*Prospecting and Mining Licenses granted in Burma during 1905 and 1906.*

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
			Prospecting Licenses.			
Akyab . .	1	255·56	Coal . .	...	...	...
Bassein . .	...	...	...	1	3,200	Coal.
Bhamo . .	1	18	Tourmaline	...	...	...
Katha . .	1	1,350·40	Coal . .	2	616·64	Gold.
Do. .	...	...	...	1	1,350·40	Coal.
Lower Chindwin.	1	12,800	Petroleum .	...	...	...
Magwé . .	1	3,200	Do. .	4	4,480	Petroleum.
Mergui . .	3	2,256·68	Tin and other minerals.	2	947·56	Tin.
Myingyan .	5	17,248	Petroleum .	6	29,845	Petroleum.
Northern Shan States.	3	15,795·2	Gold, silver, and other minerals.	1	3,200	Silver, lead, and other minerals.
Pakôkku .	...	...	...	7	8,985	Coal and petroleum.
Prome . .	1	2,560	Petroleum .	1	3,520	Petroleum.
Sagaing	...	...	...	1	426·66	Copper.
Shwebo . .	1	205·45	Gold, silver, and rubies.	1	205·45	Gold, silver, and rubies.
Southern Shan States.	...	...	...	1	18	Silver and lead.
Do. .	...	...	...	1	3,200	Coal.
Do. .	...	...	...	1	8·25	Gold.
Tavoy . .	1	224,000	Gold, silver, tin, etc.	4	263,488	Gold, silver, tin, copper, plumbago, coal, etc.
Carried over	19	...	...	34	...	

TABLE 30.—*Prospecting and Mining Licenses granted in Burma during 1905 and 1906*—contd.

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses—*contd.*						
Brought forward.	19	...	...	34	...	...
Thayetmyo .	1	100	Coal . .	...	...	...
Do. .	1	6,400	Petroleum .	3	6,778	Petroleum.
Toungoo .	...	...	...	1	3,200	Silver, lead, etc.
Upper Chindwin.	1	640	Copper .	...	...	...
Do. .	2	800	Coal . .	...	...	...
Do. .	...	...	...	1	6,400	Petroleum.
Yamèthin .	1	2,560	Tin and wolfram.	...	...	...
Do. .	...	...	...	1	5,120	Gold and tin.
TOTAL .	25	...	...	40	...	...
Mining Leases.						
Magwé . .	...	...	...	1	...	Petroleum.
Mandalay .	1	272·2	Precious stones and marble.	...	...	..
Northern Shan States.	1	2,457·60	Gold .	...	...	...
TOTAL .	2	...	...	1	...	...

TABLE 31.—*Prospecting and Mining Licenses granted in the Central Provinces during 1905 and 1906.*

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
			Prospecting Licenses.			
Balaghat	2	458	Manganese	11	7,223	Manganese and iron.
Do.	...	...	...	3	12,268	Bauxite.
Betul	...	...	...	1	37,142	Coal and petroleum.
Bhandara	4	12,099	Manganese	17	6,673	Manganese, iron-ore, and galena.
Do.	1	52	Asbestos	...	...	...
Chanda	2	12,932	Coal	...	...	...
Chhindwara	8	50,036	Do.	1	2,262	Coal.
Do.	6	8,260	Manganese	...	...	...
Jubbulpore	1	13,137	Manganese and iron.	...	...	...
Do.	3	11,403	Gold, silver, etc.	2	3,826	Gold, silver, etc.
Do.	1	447	Talc and dolomite.	...	...	...
Do.	...	...	...	1	219	Bauxite.
Nagpur	1	2,287	Manganese	9	5,463	Manganese and copper.
Do.	...	...	...	1	1,241	Coal.
Narsinghpur	1	76	Gold, silver, etc.	...	...	...
Sambalpur	1	2,037·11	Do.	...	...	...
TOTAL	31	...	...	46	...	...

TABLE 31.—*Prospecting and Mining Licenses granted in the Central Provinces during 1905 and 1906*—contd.

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Mining Leases.						
Balaghat .	...	...	...	1	8	Manganese.
Bhandara .	1	222	Manganese	...	...	...
Chanda . .	...	...	...	1	160	Iron.
Chhindwara .	1	3,827	Manganese	...	...	...
Jubbulpore .	1	9	Iron stone .	...	...	...
Nagpur .	2	126·47	Manganese	4	244	Manganese.
TOTAL .	5	...	...	6	...	...

TABLE 32.—*Prospecting Licenses granted in Eastern Bengal and Assam during 1905 and 1906.*

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Cachar . .	...	...	...	1	362,592	Mineral oil and coal.
Chittagong .	...	...	...	1	11,520	Coal, oil, gold, etc.
Khasi and Jaintia Hills	1	640	Coal and oil	...	...	...
TOTAL .	1	...	...	2	...	...

TABLE 33.—*Prospecting and Mining Licenses granted in Madras during 1905 and 1906.*

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Anantapur .	4	3,072	Gold .	1	4,095	Gold.
Bellary . .	1	143·46	Do. .	2	2,554·87	Do.
Do. . .	1	43·76	Manganese	4	5,656·76	Manganese.
Chingleput .	1	6,835·20	Coal, etc. .	...	...	...
Coimbatore .	5	138	Corundum .	...	...	...
Do. .	2	530	Gold .	...	...	...
Guntur . .	1	720	Copper .	...	...	...
Nellore . .	15	578·55	Mica .	36	886·38	Mica.
Nilgiris .	1	103·85	Gold .	1	103·85	Gold.
Salem . .	...	...	...	1	1,566·61	Corundum.
Do. . .	...	...	...	1	358·44	Magnesite.
TOTAL .	31	...	...	46	...	...
Mining Leases.						
Coimbatore .	...	...	...	1	8·28	Corundum.
Nellore . .	16	663·26	Mica .	46	2,971·59	Mica.
North Arcot .	1	10·86	Corundum .	...	...	...
TOTAL .	17	...	...	47	...	...

TABLE 34.—*Prospecting and Mining Licenses granted in the Punjab during 1905 and 1906.*

District.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Attock . .	3	1,078·75	Coal . .	1	717·25	Coal.
Jhelum . .	..	.	...	2	728	Do.
Pind Dadan Khan.	...	...	..	4	823	Do.
Shahpur .	2	670	Coal . .	1	823	Do.
TOTAL .	5	...	...	8	..	...
Mining Leases.						
Mianwáli	...	...	...	1	2,876	Coal.
Shahpur .	1	1,737	Coal . .	...	...	...
TOTAL .	1	..	...	1	...	...

TABLE 35.—*Prospecting Licenses granted in the United Provinces during 1905 and 1906.*

District.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Almora . .	2	2,075·53	Copper .	...	...	...
Garhwal .	4	3,195·70	Do. .	...	...	...
Do. .	1	1	Asbestos .	...	...	...
TOTAL .	7	...	...	0	...	...

TABLE 36.—*Summary of Concessions granted in Government lands during the ten years 1897 to 1906.*

YEAR.	Mining and Prospecting Licenses.	Exploring Licenses.	TOTAL.
1897	52	4	56
1898	85	1	86
1899	47	13	60
1900	61	11	72
1901	89	15	104
1902	89	16	105
1903	84	16	100
1904	125	26	151
1905	145	44	189
1906	211	41	252

THE AMMONITES OF THE BAGH BEDS. BY ERNEST W. VREDENBURG, A.R.S.M., A.R.C.S., F.G.S. (With Plates 14—17.)

INTRODUCTION.

THE Bagh beds is the name that has been given to some marine cretaceous strata extending up the valley of the Narbada from the neighbourhood of the plains of Gujrat to Barwaha some 240 miles from the sea-coast, when they give place to strata of fluviatile origin known as the Lameta formation. The total thickness of these interesting beds is usually insignificant, and they owe their preservation to a protective covering of basalt flows of the Deccan trap.[1] Like the Utatur beds of Southern India, they are related to the marine invasion which, in many parts of the world, marked the commencement of the Cenomanian. The only fossils from the Bagh beds that have been described and figured are the Echinoids. They include: *Cidaris namadicus* Duncan, *Salenia Fraasi* Cotteau, *Cyphosoma cenomanense* Cotteau, *Orthopsis indicus* Duncan, *Echinobrissus Goybeti* Cotteau, *Nucleolites similis* d'Orbigny, *Hemiaster cenomanensis* Cotteau, *Hemiaster similis* d'Orbigny, and were regarded by Duncan as Cenomanian in age.[2] Fossils of other zoological groups also occur, but were not critically examined.

The collections including the above fossils had been gathered partly in 1857 by Keatinge who, the year previous, had discovered the Bagh beds and recognised their cretaceous age, and by Blackwell; partly by W. T. Blanford in 1863 to 1864; and partly by P. N. Bose who between 1880 and 1883 re-visited the Bagh beds. Bose recognised three principal fossiliferous subdivisions named in ascending order the nodular limestone, the Deola and Chirákhán marl, and the coralline limestone, respectively about forty, ten, and

[1] The most complete descriptions of the Bagh beds are those by W. T. Blanford, *Mem. G. S. I.*, Vol. VI, part 3 (1869), and by P. N. Bose, *Mem. G. S. I.*, Vol. XXI, part 1 (1884).

[2] *Quart. Journ. Geol. Soc.*, XXI, p. 349 (1865); *Rec., G. S. I.*, XX, p. 81 (1887).

thirty feet in thickness. The middle subdivision is the most fossiliferous. The fauna of the other two differs mainly by the absence of some of the fossils: the majority of those that occur are also present in the Deola and Chirákhán marl, and the three subdivisions cannot be regarded as distinct palæontological zones, but merely as three successive facies of a single stage. Mr. Bose's collections are far more extensive than those gathered by his predecessors, and some preliminary determinations of the fossils given on the authority of Dr. Feistmantel were published in his account of the Bagh beds. In most cases they require confirmation by a closer study than was practicable at the time. The state of preservation of most of the gastropods and bivalves is unsatisfactory. The chief interest of Mr. Bose's collections lies in the discovery of ammonites, which, in the collections gathered by his predecessors, were represented only by a few undeterminable fragments. One species was regarded as identical with *Placenticeras tamulicum* Kossmat[1] (wrongly united by Stoliczka with *Placenticeras Guadaloupæ* Roemer = *Pl. syrtale* Morton). Though distinctly related to *Placenticeras tamulicum*, the Bagh form, on closer examination, is found to be specifically different, and will be described below as *Placenticeras Mintoi*. This is the only common ammonite in Bose's collection and many of the specimens are in a good state of preservation. They are mostly from the nodular limestone with the exception of a few specimens from the Deola and Chirákhán marl identical in all their characters with those from the underlying limestone.

In addition to the *Placenticeras* there are two remarkable species, also from the nodular limestone, each of which is represented by a solitary fragment. They belong to the same group of forms as *Placenticeras*, but differ from it generically, and do not appear to correspond exactly with any generic type that I am aware of. I have therefore proposed a new generic name *Namadoceras* to include both these species.

Since none of the three species of ammonites so far discovered correspond with any forms described from other localities, they do not help in determining the exact age of the Bagh beds with any further degree of approximation than arrived at by Duncan from a study of the

[1] The species is attributed by Kossmat to H. F. Blanford, but, as in the case of *Ammonites madraspatanus*, Blanford's name published without figure or description is nothing but a *nomen nudum*. The two species can with better justice be attributed respectively to Kossmat and Stoliczka.

Echinoids. *Placenticeras Mintoi* belongs to a group of forms ranging from the Gault to the Lower Senonian, and its presence is therefore not inconsistent with the attribution of the Bagh beds to the Cenomanian.

Genus: PLACENTICERAS Meek, 1870.

Discoidal ammonites with rather small umbilicus; shell smooth, or ornamented with spirally disposed knobs, or falciform ribs, or both; section of whorls wedge-shaped, with bevelled keel. Suture uniformly frilled by more or less pronounced marginal inflections; external saddle consisting of three sub-equal subsidiary saddles originating by subdivision of the first lateral lobe; lateral saddles variously subdivided, and auxiliary series moderately developed. Gault to Campanian.

PLACENTICERAS MINTOI nov. spec. Pls. 14, 15.

Description.—*Placenticeras* of the group of *Pl. Fritschi*, with whorls usually very convex, never greatly compressed, with a fairly broad bevelled keel limited by angular margins except in the body whorl of adult specimens when the siphonal area tends to become smoothly rounded; umbilicus deep and rather narrow; strongly projecting ornamentation consisting of three series of knobs, the coarser of which closely follow the margin of the umbilicus, the next series situated at about two-thirds of the distance from the umbilical suture to the siphonal margin, and nearly or quite as pronounced as the inner series, but usually of more elongated outline, the last series less pronounced, much more elongated, and alternating along the angular margins on either side of the siphonal keel. The knobs of the inner two series do not alternate regularly on both sides of the shell, but are not symmetrically disposed. The relative number of knobs constituting the three series are in the proportion of about three to four to six. The total number of the umbilical knobs in one whorl averages six or seven. Body chamber occupying about two-thirds of the last volution. The buccal aperture is sinuous, with rounded siphonal and lateral crests.[1]

Sutural elements entirely frilled with fine but mostly shallow marginals. Of the three subsidiary saddles, constituting the external saddle,

[1] This appears to be the first specimen of *Placenticeras* yet discovered that shows the shape of the buccal aperture.

the outermost is larger and more ramified than the next one, the third being very broad. The lobe that intervenes between the first and second saddles following the termination of the first lateral lobe is appreciably shallower, even in adult specimens, than the one separating the two following saddles. It is evident that the first and second of these saddles are subdivisions of the true first lateral saddle. This character distinguishes the sutural line of *Placenticeras Mintoi* from that of *Pl. tamulicum.*

Dimensions.—The only specimen in which the body whorl is complete (Pl. 14, fig. 1) measures 130 millimetres in diameter, the greatest thickness being 37 millimetres for a radius of 67 millimetres, avoiding the knobs in the thickness measurement. The species grew to a much larger size than is shown in the above figures. Another specimen is entirely chambered up to a radius of 70 millimetres and must have been at least 180 millimetres in diameter. The sutures of this specimen are shown on Pl. 14, fig. 2. At a radius of 69 millimetres, the thickness is 40 millimetres, the ratio being about the same as in the previous specimen. The shape of the section of this specimen is shown on Pl. 15, fig. 2. Both the above-mentioned individuals belong to the more compressed variety of the species, the degree of flattening never amounting to what one observes in certain specimens of *Placenticeras tamulicum.* In other specimens the ratio of thickness to radius varies from $\frac{3}{5}$ to $\frac{3}{4}$. The greatest thickness is close to the umbilical suture. (See the sections represented on Pl. 15.) The section of an inflated specimen, Pl. 15, fig. 3, shows that at a diameter of 21 millimetres this ammonite exhibits the compressed shape common to all species of *Placenticeras* in their early stages.

The ratio between the height of the whorls (measured from the keel of the previous whorl), and the corresponding radius, is about $\frac{6}{11}$, and is the same both for compressed and inflated varieties.

Certain specimens, such as the one shown on Pl. 15, figs. 1, 1*a*, assume the adult characteristic of a rounded siphonal margin at a comparatively small size. They seem therefore to be full-grown or nearly so. These differences of size, observed in many species of ammonites, are perhaps a sexual character, as has already been suggested by several naturalists.

Development of suture.—The clearness with which the sutural line exhibits the mode of origin of its elements distinguishes this form from other allied species, none of which, with the exception of

Placenticeras pacificum, preserve the individuality of the first lateral saddle in so pronounced a manner. Mr. Bose's collection includes numerous specimens of all sizes, and in the smaller ones the individuality of the original elements is still more pronounced. The specimens of *Placenticeras tamulicum* in the Indian Museum are all of large size, so that it is not possible to compare this feature at its earlier stages with *Placenticeras Mintoi.* The latter in specimens of small size exhibits some very interesting and instructive features, clearly showing the manner in which the complex subdivisions originate: at a diameter of as much as 72 millimetres, the outermost adventitious lobe is of much smaller size than the two following ones, a character which persists in the adults of the Gault and Cenomanian species *Placenticeras Ebrayi* and *Pl. saadense;* the third adventitious saddle appears as a mere indentation of the first lateral lobe. The derivation from the true first lateral saddle of the two inflections simulating a first and second lateral saddle which is indicated even in the adult by the relatively small size of the lobe between them is absolutely evident in small specimens of the size just referred to where the lobe between them is a mere notch at the summit of the massive first lateral saddle (Pl. 14, fig. 3).

But for the inequality that subsists in the lateral elements in the adult, the suture closely resembles that of *Placenticeras tamulicum.* Although the inequalities of the lateral inflections in young specimens of *Placenticeras Mintoi* tend to become equalised as the shell grows up, yet the relatively small size of the adventitious lobe subdividing the first lateral saddle remains perfectly appreciable even at a radius of 65 millimetres (Pl. 14, fig. 2), while nothing of the sort can be detected in specimens of *Placenticeras tamulicum* of the same dimension, or even down to a radius of 45 millimetres, the smallest size at which I have been able to observe clearly the sutures of the south Indian species. Apart from this detail, the sutures in adult specimens of both species are almost identical. The third adventitious saddle is usually more slender in *Placenticeras tamulicum* than in *Pl. Mintoi;* yet in certain individuals of the South Indian form, such as the large specimen represented on Pl. XLVII of Stoliczka's work on the cretaceous ammonites of Southern India (the suture of which is not figured), it has the same broad shape as is usually observed in the Bagh species.

This interesting Indian ammonite is dedicated to His Excellency the Earl of Minto, Viceroy of India.

Localities and geological horizon.—This ammonite occurs in great abundance in the nodular limestone, where it has been collected by Mr. Bose at a large number of localities. It is found somewhat more sparingly in the overlying Deola and Chirákhán marl, the specimens from this bed being in every respect similar to those of the nodular limestone.

Relation to other species.—This species, although related to *Placenticeras tamulicum*, differs from it in its usually much stouter shape and especially in its ornamentation. It has more convex whorls than any other *Placenticeras* yet described. The protuberances of the second row are much more pronounced than in the South Indian species, and those of the third row, along the keel, much fewer.

All the above characters are variable in both species, yet even at their extreme limits there is no possible ambiguity, especially as the several characters do not vary simultaneously in the same direction: for instance, although the thickest specimens of *Placenticeras tamulicum* may be as massive as the thinnest ones of *Pl. Mintoi*, the increase in thickness is not accompanied by a reduction in the number of protuberances, or by an increase of their dimensions, or any other approach towards the characters of *Placenticeras Mintoi*. The variations in the suture of *Placenticeras tamulicum* are quite independent of the shape of the shell.

The irregularity of the progression in size of the lateral lobes and saddles differs from that figured for other species. In the degree of marginal frilling of the inflections, it is related to *Placenticeras tamulicum* and *Pl. Fritschi*. The small size of the inflection simulating a first lateral lobe, especially in young specimens where it appears as a mere indentation of the first lateral saddle, clearly shows the mode of origin of the three inflections which, in most species of *Placenticeras*, seem to represent the two lateral and first auxiliary saddle, while in reality they only represent the two lateral ones. It so happens, however, that in the one species whose ontogeny has been completely studied, *Placenticeras californicum* (Perrin Smith, *Proceedings of the California Academy of Sciences*, 3rd series, *Geology*, I, p. 181, 1900), the first lateral saddle never loses its individuality, still less even than in *Placenticeras Mintoi*.

Grouping of species.—Up to the present, there have been described 19 species of *Placenticeras* which can be grouped in four sections. They are enumerated and briefly diagnosed in the following list.

SECTION I.

1. PLACENTICERAS MEEKI Böhm, 1898.

Zeitschrift der deutschen geologischen Gesellschaft, L, p. 200. Meek, Invertebrate Cretaceous and Tertiary Fossils of the Upper Missouri Country, p. 465, Pl. XXIV, fig. 2 (1876).

Greatly compressed, with narrow keel; smooth; suture extremely ramified, more so than in any other species. Campanian (Fort Pierre group).

2. PLACENTICERAS PLACENTA Dekay, 1828.

Whitfield, Gasteropoda and Cephalopoda of the Raritan Clays and Greensand Marls of New Jersey, p. 255, Pls. XI, XLI, figs. 1, 2 (1892).

Compressed; smooth, except for a row of umbilical knobs; suture greatly ramified. Campanian.

3. PLACENTICERAS KHARASMENSE Romanofsky, 1884.

Materials for the Geology of Turkestan, II, p. 134, Pls. II, III, fig. 1.

Compressed; smooth, except for a row of weakly developed umbilical knobs; sutural inflections very finely frilled and deeply ramified. Probably Campanian.

So far as can be made out from published figures, the distinctness of this species from *Pl. placenta* is doubtful.

4. PLACENTICERAS BIDORSATUM Roemer, 1841.

Schlüter, Cephalopoden der oberen deutschen Kreide, *Palæontographica*, XXI, p. 51, Pl. XV, figs. 6-8 (1872).

Greatly compressed; keel very narrow; smooth, except for a row of knobs along the external shoulders of adults; sutural inflections much ramified. Campanian.

5. PLACENTICERAS INTERCALARE Meek, 1876.[1]

Loc. cit., p. 468, Pl. XXIII.

[1] If, as suggested by Whitfield and by Böhm, one of the two forms described by Meek from the Fort Pierre group is to be specifically separated from the original *Pl. placenta*, the second one can no longer be considered as a variety, but must also be regarded as a distinct species. By their sutural lines, the two Fort Pierre forms are much more nearly related to one another than to *Pl. placenta* of New Jersey. If the smooth-shelled form, Pl. XXIV of Meek's monograph, be separated from *Pl. placenta* under the name of *Pl. Meeki* Böhm, there is no reason for maintaining the tuberculated form *intercalare*, Pl. XXIII, as a variety of *Pl. placenta* rather than of *Pl. Meeki*.

Compressed, with narrow keel; rather numerous small, not very prominent knobs, disposed in three rows, one along the umbilical and one along the external margin, and one intermediate one; suture greatly ramified, closely resembling that of *Pl. Meeki.* Campanian (Fort Pierre group).

6. PLACENTICERAS SUBTILISTRIATUM Jimbo, 1894.

Beiträge zur kentniss der Fauna der Kreideformation von Hokkaido. *Palaeontologische Abhandlungen*, VI, p. 171, Pl. XVII, fig. 1, 1894.

Described from immature specimens of a size at which the characters cannot be depended upon for specific distinction. Considering that the suture is described as complicated and deeply ramified even at the immature stage of the specimens, it is probable that the species belongs to the group of *Placenticeras placenta.* Exact horizon unknown.

7. PLACENTICERAS TELIFER Morton, 1834.

Whitfield, *loc. cit.*, p. 257, Pl. XLI, figs. 10, 11.

Fragments too incomplete for diagnosis; all that can be recognised is that the suture is greatly frilled and ramified, and that the species attained large dimensions. It perhaps belongs to the group of *Placenticeras placenta*, and like it is found in New Jersey, but probably at a lower horizon, which may be the base of the Campanian, or the summit of the Santonian.

SECTION II.

8. PLACENTICERAS SYRTALE Morton, 1834.

De Grossouvre, Les Ammonites de la Craie supérieure, p. 128, Pl. V, fig. 3; Pl. VI, figs. 1, 2; Pl. VII, fig. 1; Pl. VIII, fig. 1 (1894).

Whorls usually thick, keel relatively broad; at intermediate stages of growth there are three series of prominent knobs or denticulations, external, umbilical, and intermediate, but the two inner series gradually move outwards as the specimens approach maturity, till the denticulations along the keel become completely displaced by the knobs of the second row. The three adventitious saddles constituting the compound external saddle gradually decrease in size as they recede from the siphonal margin; the gradation continues regularly through the succeeding lateral and auxiliary inflections, so that the original irregularities of progression in size of the sutural elements are almost entirely

obliterated. Inflections moderately frilled, and very little ramified, Santonian.

SECTION III.

9. PLACENTICERAS PRUDHOMMEI Peron, 1897.

Les Ammonites du Crétacé Supérieur de l'Algérie, *Mém. Soc. Géol. de Fr.*, No. 17, p. 56, Pl. IX, figs. 3-7; Pl. XVII, fig. 8.

Compressed; keel rather narrow; umbilical and marginal tubercles distinct, intermediate ones indistinct The characters of the suture cannot be clearly made out, the one figured belonging apparently to a immature specimen. Lower Senonian.

10. PLACENTICERAS CALIFORNICUM Anderson, 1900.

Perrin Smith, The Development and Phylogeny of *Placenticeras*, *Proc. Cal. Acad. of Sc.* (3rd ser.), *Geology*, Vol. I, p. 203, Pl. XXV, figs. 1-8; Pl. XXVIII, fig. 6.

Rather compressed; keel fairly broad; sides ornamented with rough sigmoidal ribs; two series of knobs, coarse ones round the umbilical margin, and small elongated ones along the margin of the keel. Details of the suture have not been published, but judging from the description, it is related to that of *Pl. tamulicum* and *Pl. pacificum.* Lower Senonian (Chico = Trichinopoli).

11. PLACENTICERAS PACIFICUM Perrin Smith, 1900.

Loc. cit., p. 207, Pl. XXIV, figs. 1-21; Pl. XXV, figs. 9-11; Pl. XXVI; Pl. XXVII, figs. 1-13; Pl. XXVIII, figs 1-5.

Compressed; keel moderately narrow; sides ornamented with falciform ribs; umbilical and external knobs small, but distinct, intermediate ones indistinct; sutural elements finely frilled, and with deep ramifications which are neither so numerous nor so regularly disposed as in the *Pl. placenta* group; individuality of the first lateral saddle very distinct. Lower Senonian (Chico = Trichinopoli).

12. PLACENTICERAS TAMULICUM Kossmat, 1895.

Untersuchungen über die südindische Kreideformation, p. 78, Pl. VIII, fig. 1.

Thickness usually moderate, but very variable; keel usually moderately broad; pronounced umbilical knobs, and rather numerous pronounced denticulations on the margins of the keel; the intermediate series of swellings inconspicuous; suture moderately frilled and ramified. Lower Senonian (Trichinopoli).

13. PLACENTICERAS FRITSCHI de Grossouvre, 1894.

Les Ammonites de la Craie Supérieure, p. 124, Pl. V, figs. 1, 2.

Moderately compressed; keel relatively broad; closely similar to *Pl. tamulicum*, except that the angular margins of the keel are smooth. Coniacian.

14. PLACENTICERAS MEMORIA SCHLOENBACHI Laube and Bruder, 1887.

Ammoniten des böhmischen Kreide, *Palæontographica*, Vol. XXI, p. 221, Pl. XXIII.

Much compressed; keel very narrow; only the umbilical knobs developed; suture resembles that of the two preceding species. Turonian.

15. PLACENTICERAS SAADENSE Thomas and Peron, 1889-90.

Description des mollusques fossiles des terrains crétacés de la région sud des hauts-plateaux de la Tunisie, p. 19, Pl. XVI, figs. 3-7.

Compressed; apparently smooth; the suture, so far as can be made out, is moderately frilled and ramified, and has unequal inflections betraying their mode of origin even in the adult; the outermost adventitious lobe is rather shallow as in *Pl. Ebrayi*, and in immature specimens of *Pl. Mintoi*. Cenomanian.

16. PLACENTICERAS MINTOI Vredenburg, 1907.

Whorls very thick; keel rather broad; three series of pronounced, widely spaced protuberances, along the margins of the umbilicus and of the keel, and along the external shoulders; suture moderately frilled and ramified; unequal lobes in the lateral series, plainly showing that the first lateral saddle consists of two subsidiary saddles. Cenomanian.

17. PLACENTICERAS UHLIGI Choffat, 1886.

Recueil d'études paléontologiques sur la faune crétacique du Portugal, p. 4, Pl. II, figs. 3-5.

Shell ornamented with falciform ribs and with tubercles along the margins of the umbilicus and keel; sutures moderately frilled and ramified.[1]

[1] I have not had access to the original description of the species; the characters here given are incidenta y mentioned by Thomas and Peron in the description of *Pl. saadense*.

18. PLACENTICERAS EBRAYI de Loriol, 1882.

Études sur la faune des couches du Gault de Cosne (Nièvre), p. 7, Pl. I., *Mém. Soc. Pal. Suisse*, Vol. IX, part 2.

Whorls moderately thick; keel moderately wide; four rows of tubercles: along the margins of the umbilicus and keel, and two intermediate series; sutural inflections moderately frilled and ramified; the outermost adventitious lobe, even in very large specimens, is shallow as in *Pl. saadense* and in immature specimens of *Pl. Mintoi*, Gault.

SECTION IV.

19. PLACENTICERAS WARTHI Kossmat, 1895.

Loc. cit., p. 176, Pl. VI, fig. 8.

Compressed; smooth; outermost subsidiary saddle split into two portions by a deep adventitious lobe, so that the external saddle appears divided into four portions instead of three; the suture has numerous inflections, but is very slightly frilled, the summit of the saddles being almost devoid of marginals with the exception of a deep narrow median notch. Gault (Maravatur beds).

By grouping the species as proposed in the above list, the first section might be distinguished as the group of *Placenticeras placenta*, characterised by compressed shells with a very narrow keel, delicate or obsolete ornamentation, and an extremely frilled and ramified suture. The species of this group are very closely related to one another. They appear to be restricted to the Campanian.

The second section including *Placenticeras syrtale* and its numerous varieties is characterised by prominent tubercles which gradually travel outwards as the shell grows larger, and by a sutural line remarkable for the great sameness of successive inflections, all of which are almost devoid of deep ramifications. The ammonites of this section belong to the Santonian.

The third section, including the greatest number of species, may be called the group of *Placenticeras Fritschi*. The ammonites of this group have variously ornamented shells of variable thickness, the knobs occupying the same relative position at all stages of growth, the sutural line moderately frilled and ramified, with inflections of irregularly progressing dimensions. They range from the Gault to the Lower Senonian.

The fourth section only includes the aberrant *Placenticeras Warthi* with smooth compressed shell, and a sutural line which is greatly subdivided but scarcely frilled or ramified. The mode of origin of the adventitious inflections which can be distinctly traced, even in the adult, agrees with what is observed in other species, and clearly shows that it is a normal *Placenticeras* in spite of its aberrant characters. Its age is Albian.

The following table gives the distribution in time of the various species so far as is known:—

		Gault.	Cenomanian.	Turonian.	Lower Senonian.	Campanian.
I	*Pl. Meeki* Böhm	....	....	....	....	————
	„ *placenta* Dekay	....	....	....	....	————
	„ *kharasmense* Romanofsky . .	....	....	....	....	— ? —
	„ *bidorsatum* Roemer . . .	....	....	....	....	————
	„ *intercalare* Meek . . .	.....	....	....	....	————
	„ *telifer* Morton	....	....	....	... —?	—
II	„ *syrtale* Morton	....	....	....	———	
III	„ *Prudhommei* Peron . . .	....	....	....	————	
	„ *californicum* Anderson . .	....	....	....	————	
	„ *pacificum* P. Smith . . .	....	....	....	————	
	„ *tamulicum* Kossmat . . .	....	....	....	————	
	„ *Fritschi* de Grossouvre . .	....	....	....	———	
	„ *mem. Schloenbachi* Laube and Bruder.	....	....	————		
	„ *saadense* Thomas and Peron . .	....	————			
	„ *Mintoi* Vredenburg . . .	....	————			
	„ *Uhligi* Choffat	...———	—			
	„ *Ebrayi* de Loriol	————				
IV	„ *Warthi* Kossmat	————				

It will be noticed that the species of the oldest group, that is, *Placenticeras Warthi*, exhibits the simplest outlines of sutural inflections, while in the newest group, that of *Pl. placenta*, they are extremely ramified; this is in accordance with the order usually observed in the development of other genera of ammonites. The generality of this law amongst the ammonites appears to indicate that each genus started with a relatively thick-shelled form succeeded by gradually thinner-shelled species. Since the degree of complexity of the sutures is obviously correlated with the delicacy of the shell, the manner in which this character is taken to indicate progress or regression is scarcely justified, considering that it cannot have borne any relation to the degree of complexity of the organisation.

Genus: NAMADOCERAS gen. nov.

Definition.—Smooth ammonites with wedge-shaped acutely keeled whorls, each of which completely encloses the previous one, leaving a funnel-shaped umbilical depression; sutural line finely frilled throughout its entire length, consisting of a broad external saddle divided into two main portions by a deep adventitious lobe, followed by a moderately developed lateral and auxiliary series of gradually dwindling marginally frilled inflections.

Owing to the fragmentary condition of the specimens, nothing is known regarding the shape and size of the body chamber.

Relation to other genera.—This type is somewhat of a connecting link between the genera *Placenticeras* and *Sphenodiscus*, though not intermediate between them. The shape is that of *Sphenodiscus*, but the suture recalls that of *Placenticeras*, differing, however, from both these genera owing to the subdivision of the compound external saddle into two principal masses instead of three. The resemblance of the sutural line to that of *Placenticeras* is especially marked in one of the two species, the one which I have named *Namadoceras Scindiæ*, where the more external of the two masses constituting the external saddle is itself subdivided in such a manner as to suggest a tripartite subdivision of the whole lobe not unlike that observed in *Placenticeras*. Only if the lobe be thus regarded as tripartite, the middle subdivision is of insignificant size as compared with its development in all the species belonging to the remarkably homogeneous genus *Placenticeras*;

while the same interpretation removes it still further from the characteristic Senonian forms of *Sphenodiscus*, in which the middle adventitious saddle is always as large or larger than one or other of its fellows. In the Turonian *Sphenodiscus Requieni* d'Orbigny, the second adventitious saddle is small, but still the suture differs considerably from that of *Namadoceras*, owing to the much simpler outline of the saddles, especially in the lateral and auxiliary series.

Apart from the differently constituted external saddle, the general appearance of the suture recalls that of *Placenticeras*. The marginal inflections are very similar, and the lobes and saddles are arranged very similarly as regards shape and disposition. The absence of knobs and the sharp non-bevelled keel produce an external appearance different from that of *Placenticeras*, but analogous to that of *Sphenodiscus*.

With regard to the suture, in addition to the different constitution of the external saddle, *Namadoceras* is distinguished from *Sphenodiscus* by its less complex auxiliary series. This smaller development of the auxiliary series and the greater development of marginals round the saddles distinguishes it from *Indoceras* which, like *Namadoceras*, has a bipartite external saddle.

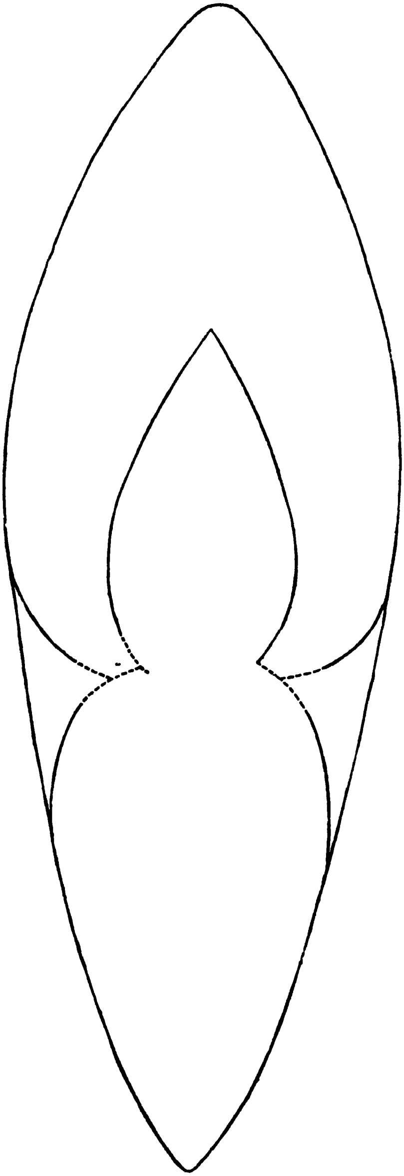
The genus is perhaps related to certain neocomian forms, such as *Ammonites Gevrilianus* d'Orbigny, which have sometimes been regarded as related to *Oxynotoceras*. It is also related to *Ammonites Cleon* d'Orbigny of the Gault, and also to the already mentioned *Sphenodiscus Requieni* of the Turonian.

Its closest ally is probably the neocomian genus *Leopoldia* Baumberger, a genus related to *Hoplites*, and distinguished from *Namadoceras* by the bluntness of its keel, its frequently ornamented shell, and the less pronounced splitting up of the external saddle.

At any rate there is no doubt as to the propriety of including *Namadoceras* amongst the Placenticeratidæ, or "Placenticeratinæ," if the group be regarded as a sub-family of the Hoplitidæ.

NAMADOCERAS SCINDIÆ nov. spec. Pl. 16.

Description.—Smooth shell with deeply frilled sutures, the external half of the complex external saddle greatly ramified, and subdivided, on its inner side, by a marginal lobe so deep as to isolate an almost independent subsidiary saddle; inner half of the external saddle broad, and less deeply ramified, separated by a large complex first lateral lobe from the large first lateral saddle which has a tendency to become bifid; the second lateral lobe and saddle smaller and less complex, followed by a well marked lobe and a low auxiliary saddle beyond which the auxiliary series extends down the umbilical funnel in a serrated line the inflections of which are not distinctly individualised.



Section of *Namadoceras Scindiæ.*

Dimensions.—The solitary fragment is entirely chambered up to its largest radius of 92 millimetres. The species must grow therefore to a very large size. The ratio between the height of a whorl and the corresponding radius is about 5 to 9. The greatest thickness situated at a little less than one-third of the radius from the centre is 56 millimetres at a corresponding radius of about 90 millimetres.

I have dedicated this remarkable ammonite to His

Highness the Maharajah Aleejah Bahadur Scindia in whose dominions the Bagh beds are extensively developed in a series of most interesting exposures.

Locality and geological horizon.—The solitary specimen was discovered by Mr. P. N. Bose in the nodular limestone at Mongra in Chota Udaipur.

NAMADOCERAS BOSEI nov. spec. Pl. 17.

Description.—Shell with slightly developed straight radial folds, especially distinct towards the umbilicus, becoming gradually effaced towards the attenuated, very sharp marginal keel; sutural line moderately frilled, the outer half of the complex external saddle being the only portion deeply ramified; first lateral saddle large and broad, followed by second lateral lobe and saddle, first auxiliary lobe and saddle, and second auxiliary lobe, of gradually decreasing size, beyond which the suture is concealed by the matrix filling the umbilical funnel. All the inflections are somewhat uniform in outline, the saddles tending to a bifid, and the lobes to a trifid disposition.

Dimensions.—The greatest radius of the entirely chambered fragment must have been about 80 millimetres indicating, as in the case of the previous species, an ammonite of large dimensions. The greatest thickness situated at a little over one-quarter the radius from the centre is about 30 millimetres at a radius of 65 millimetres, or $\frac{6}{13}$ of the corresponding radius. The state of preservation of the fragment does not allow an exact measurement of the rate of involution.

Comparison with the previous species.—The shell is somewhat more compressed than that described as *Namadoceras Scindiæ*, but with only one specimen of each species it is not possible to say how far this may be merely an individual accident. The radial folds and the pinched tapering shape of the section towards the keel in *Namadoceras Bosei* are conspicuous distinctions. The sutural line is quite different. It is less minutely frilled and the development of the larger inflections is more pronounced towards the umbilicus and less so towards the external margin in *Namadoceras Bosei* than in *Namadoceras Scindiæ*.

There is no marked tendency towards the individualisation of a median adventitious saddle in the complex external saddle, such as is observed in *Namadoceras Scindiæ*, though this inflection is represented

in a rudimentary manner by a small marginal saddle deeply situated in the adventitious lobe that separates the two masses of the compound external saddle.

Locality and geological horizon.—There is only one specimen which was discovered at the same locality and at the same horizon as the one fragment of the previously described species. The simultaneous occurrence of two completely distinct forms of such a remarkable generic type is a most interesting circumstance.

I have dedicated this second species to its discoverer, my colleague Mr. P. N. Bose.

LIST OF ILLUSTRATIONS.

All the figures are drawn in natural size.

MISCELLANEOUS NOTES.

A Bituminous Limestone from the Vindhyan Series, Jodhpur State.

A SAMPLE of rock received from the State Engineer, Jodhpur State, Rájputána, and described as having a smell of kerosine oil, consists of several pieces of a dark hair-brown limestone. In some cases the grain is fairly fine (19·167); but in others the rock is very coarsely crystalline (19·168), the cleavage faces being so markedly curved that in one case, where a curved cleavage face two inches across was obtained, the curvature corresponded to that of a circle about 4 inches in diameter. The accompanying woodcut shows a corner where three of these curved cleavage faces, corresponding to those of the unit rhombohedron, meet.

Curved cleavage.

On inspecting the hand-specimen each of the curved cleavage faces is seen to be composed of a number of much smaller facets arranged so as to make small angles with one another. This, of course, accounts to a certain extent for the curvature, but not entirely, for each of these smaller cleavage facets is seen by the aid of a lens to be itself curved. The microscope also shows that although many of the cleavages are composite and owe their curvature to a stepped or *en échelon* arrangement of smaller cleavage cracks, yet many of the curved cleavages are bold and distinct and undoubtedly quite simple. As the large plates of calcite show no signs of strain phenomena in the shape of undulatory extinction or lamellar twinning, the curved cleavâge cannot be ascribed to strain; and the only reason that can be advanced to account for the departure of the cleavage of this calcite from that of normal calcite is that possibly the included bituminous matter, to be referred to below, has some effect on the disposition of the calcite molecules.

Curved faces of *crystallization,* usually made up of sub-individuals, are of common occurrence with the allied minerals dolomite and chalybite;

but I am not aware that curved *cleavage* faces have been recorded for any of the minerals of this group, except possibly in the case of obviously strained individuals seen in microscope sections.

The specific gravities of a piece of the finer-grained and of the more coarsely crystalline rock were found to be 2·71 and 2·68 respectively.

The rock has a strong fetid or bituminous smell which is stronger on fresh fractures than on old. On dissolving a portion of the rock in dilute hydrochloric acid a brown scum is formed. This is taken up by ether, which then burns with a smoky flame. The rock also gives a slight reaction for sulphur.

Bituminous character.

Under the microscope the rock shows pale yellowish plates of calcite ophitically enclosing abundant little patches of what seems also to be calcite in different optic orientation to the enclosing plates.

Traversing the yellowish calcite are veinlets of quite clear and colourless calcite. The way in which the bituminous matter occurs is not apparent in the microscope sections, but it may either be uniformly distributed through the yellowish calcite, thus accounting for the colour of the latter, or, less probably, associated with the above-mentioned little patches of calcite (?) enclosed in the larger calcite individuals.

The rock was found near Bilara, and the exact locality is given as "two miles off from Pichak village on the way to Kharya and Udalyawas and about 100 yards north of bank No. II of Jeswant Sagar Tank." This is at lat. 26° 12′ and long. 73° 46′, in Jodhpur State, and is on the Vindhyan formation.

Hence we see that this rock is to be regarded as a bituminous limestone of Vindhyan age.

[L. L. FERMOR.]

Wavellite from the Singhbhum district, Bengal.

Amongst some specimens received from M. R. Ry. Srinivasa Rao, B.A., in 1906, was one (K. 4) showing numerous radiate tufts forming incrustations on, and filling cracks in, a dark grey flint-like quartzite which under the microscope is seen to be composed of a very fine-grained quartz aggregate. The radiate tufts are 0·5 to 1·5 cm. in diameter and of a pale greenish white colour. The mineral suggests wavellite in its general appearance; and that it is this mineral is shown by the fact that it reacts for phosphorus, aluminium, and water. The specific gravity of a small piece was found by means of Sonstadt's solution to be 2·345; this is a trifle higher than the value given by Dana, 2·316 to 2·337. Wavellite has apparently not been previously recorded from India.

The specimen was collected at Gobindpur—lat. 22° 37'; long. 85° 36'—about half-way between Chakardharpur and Sonua station, Bengal-Nagpur Railway, the district being Singhbhum, Bengal.

[L. L. FERMOR.]

Corundum from the Singhbhum district, Bengal.

Amongst the specimens received from M. R. Ry. Srinivasa Rao were several pieces (19·299 to 19·302) of heavy, light greyish and brownish rocks from Lopso Hill, Singhbhum; Lopso Hill is situated about 11 miles North-East of Chakárdharpur station, Bengal-Nagpur Railway (lat. 22° 47': long. 85° 47'). The specific gravity of the rocks ranges from 3·57 to 3·67. The hardness of the specimens indicates at once the presence in the rock of corundum, and the microscope shows that these rocks are granular crystalline aggregates of corundum, containing a certain amount of tremolite, which in some places is aggregated into tufts conspicuous in the hand-specimen. This is a new locality for corundum-bearing rocks in India; Mr. Hallowes who has visited Lopso Hill says that he was only able to find pebbles of these rocks and not to find them *in situ*.

[L. L. FERMOR.]

Apatite-magnetite-rock from the Singhbhum district, Bengal.

Amongst some samples of iron-ores from two villages given as Moosalbali and Pathorghora[1] in Prince Mahomed Bukhtiyar Shah's Dhálbhum Estate, Singhbhum district, Bengal, were several specimens of an interesting apatite-magnetite-rock. The apatite occurs as flecks and spots, sometimes up to ½ inch in diameter, and of a creamy colour, often tinged brown by iron oxide, in what would otherwise be called magnetite-rock. There is one patch, composed almost entirely of apatite, that is 2½ inches long by 1½ broad. The mineral gives all the test of apatite, and is seen under the microscope to have been formed later than the magnetite, which is idiomorphic with respect to the apatite. In many places the interstices of the magnetite are occupied by a golden-coloured micaceous mineral in the place of the apatite, with which it is also sometimes associated. A little quartz occurs in one place and is idiomorphic with respect to the apatite.

In the absence of any information as to the mode of occurrence of this rock or ore, it is difficult to put forward any theory as to its origin.

If this rock occur in any quantity, it might be of considerable value, on account of the considerable percentage of phosphorus it must contain, in the manufacture of basic steel.

[L. L. FERMOR.]

[1] Probably the same as Mosaboni (lat. 22° 31'; long. 80° 30') and Patholgora (lat. 22° 32'; long. 86° 29') shown on Standard Sheet No. 186 of the Bengal Survey (Reg. No. 786 S.—05).

Note on the Occurrence of Orpiment on the Shankalpa Glacier, Kumaon.

That orpiment occurs in some locality near Munsyari (80° 18′; 30° 7′) has been already pointed out in these *Records* (Vol. II, page 88), but the precise position was apparently unknown.

In September 1906, when visiting the Shankalpa glacier (80° 24; 30 19) we found upon the surface-moraine of the glacier, and about one mile from the ice-cave, scattered fragments of orpiment-bearing rock, showing upon the freshly fractured surfaces minute specks of realgar. The ore covers only a very limited portion of the surface-moraine, and appears to be scattered upon it in the form of an ellipse perhaps ¼ mile in length, and lying close to the north-west side of the valley about one mile from the ice-cave. Outside the margin of this ellipse we found no ore.

It seems probable that the ore has not been carried very far from its home by the flow of the glacier-ice, for if it had been brought down in the same manner as the surface-moraine of the glacier, we should expect to find it distributed throughout the latter and not confined to one particular place. Possibly it may have been carried down by an avalanche from the hill-side. The absence of realgar on the weathered surface of the specimens may possibly indicate that the rock has been exposed to the air for a considerable time; this however is doubtful.[2]

We were unable to discover the source of the fragments both owing to the short time at our disposal and being hampered by fresh falls of snow on slopes ordinarily difficult on account of their great steepness.

The orpiment occurs filling in irregular veins and cracks in a bluish-grey siliceous rock, and is found in foliated masses of a lemon-yellow colour. No crystal faces can be determined although the cleavage is especially well-marked. A specimen of the pure mineral was found to have a specific gravity of 3·45.

Realgar in small granules of the usual red colour is of rare occurrence and is seen only on the freshly fractured surface.

An average sample of about 2,000 gms. of the mineral and gangue was powdered for chemical examination. A determination made by Mr. Brown on material from this shows that the rock contains 23·11 per cent. of arsenic.

[G. DEP. COTTER AND J. COGGIN BROWN.]

[1] See also: Mallet, Manual of the Geology of India, Part IV, page 12, and Atkinson, Economic Mineralogy of the Hill Districts of the North-West Provinces of India, page 31.

[2] Dana, System of Mineralogy, page 34. "Realgar changes to orpiment and arsenolite on exposure to light."

Note on the Tatkan area : blocks 21—26-N, Yenangyaung.

These blocks have been regarded as of Irrawadi sandstone age by Grimes (*Mem. G. S. I.*, XXVIII, p. 60); but the presence of large exposures of clay beds have caused subsequent investigators of these blocks to regard them as possibly Yenangyaungian.

I examined these blocks in April 1907, with the object of determining (1) the age of the clay exposures, and (2) the structure of the strata, whether anticlinal or otherwise.

The clay beds appear to me to be of Irrawadi sandstone age for the following reasons:—

(1) The sandstones exposed in this area are typical Irrawadi sandstones, showing everywhere current-bedding, and containing fossil wood, and they are interstratified with numerous pebble beds (see *Mem. G. S. I.*, XXVIII, p. 70).

(2) The so-called clay beds are, I think, merely large clay pockets in the sandstones, and are of contemporaneous age. Many sections in the stream beds, which I examined, supported this view; thus in the Ngamwe Chaung, a large clay pocket is exposed showing sandstones enclosing it. The clay of these pockets is of an exactly similar type to those of the exposures in the Kyubyu and Thitnyodaw Chaungs, blocks 24 and 26-N, Yenangyaung, where the sandstones apparently overlie the clays with local unconformity, because, as I think, the sections are not deep enough to show the lower boundaries of the pockets.

(3) Although gypsum has been reported from these blocks, it appears to be very scarce. In the Yenangyat area gypsum is also found in the Irrawadi series in small quantity.

(4) The clay of these exposures differs from Yenangyaungian clays in that it is jointed, not laminated or bedded, and it may well be a fresh-water deposit.

(5) The well-sections of the two wells drilled in this area show a series of soft sandstones and clays with bands of siliceous pebbles; these occurrences are suggestive of an Irrawadi sandstone age.

Structure.—After a careful examination of the structure, I came to the conclusion that the strata are slightly undulatory and practically horizontal. The exact dip is often unobtainable owing to the prevalence of current-bedding and the softness of the sandstones.

If the above views be correct, the prospects of oil in these blocks are almost hopeless.

[G. DEP. COTTER.]

Fossils from the Miocene of Burma.

A collection of fossils has been received from Mr. L. G. Boyd, of which 12 species come from Singu, 23 species from the southern continuation of the Gwegyo anticline, now known as the Payagyigon-Ngashandaung oil-field, 8 from Padaung near Prome, 5 from the Kabat anticline, 2 from Taungtha Hill, and 3 from the hills near Kwatalin 20 miles south of Taungtha. The following is a list of the species from the different localities :—

Singu.—

Pecten kokenianus Noetl.
Arca yawensis Noetl.
Tellina grimesi Noetl.
„ *indifferens* Noetl.
„ *protocandida ?* Noetl.
Lithodomus sp.
Vermetus sp.
Oniscidia minbuensis ? Noetl.
Voluta ringens Noetl.
Conus malaccanus ? Hwass.
Cassis d'archiaci Noetl.
Balanus tintinnabulum Linné.

Payagyigon-Ngashandaung field.—Of the 27 species from this area, 15 come from a locality one mile west-south-west of Payagyigon village, and it seems probable that they represent the zone of *Paracyathus cæruleus* Noetling. The following is a list :—

Tellina indifferens Noetl.
Scalaria sp.
Terebra ? sp.
Mitra sp.
Rimella crispata Sow.
Cancellaria davidsoni d'Arch. and Haime.
„ *martiniana* Noetl.
Voluta dentata Sow.
Oliva rufula Duclos.
Cypræa granti d'Arch. and Haime.
Drillia yenanensis Noetl.
„ *protointerrupta* Noetl.
Surcula feddeni Noetl.
Pleurotoma cf. woodwardi Martin.
„ *cf. tigrina* Martin.

Other species from unstated localities in this field are as follows :—

Temnopleurus sp.
Tellina protostriatula ? Noetl.
" *grimesi* Noetl.
Ficula theobaldi Noetl.
Calliostoma sp.
Siliquaria sp.
Drillia protocincta ? Noetl.
Basilissa lorioliana Noetl.
Oniscidia minbuensis ? Noetl.
Ceratotrochus alcocki Noetl.
Nautilus sp.
Balanus tintinnabulum Linné.

It is interesting to note that the fossils from this field have been subjected to considerable pressure, many of them having been squeezed flat. For this reason also they are often too badly preserved for accurate determination.

Padaung (*Prome*).—The following fossils were obtained from a reef in the Irrawadi river :—

Tapes protolirata Noetl.
Dione protolilacina Noetl.
Solarium sp.
Meiocardia sp.
Cucullæa protoconcamerata Noetl.
Arca sp.
Turrilla acuticarinata Dunker (some specimens showing forms which are intermediate between this species and *T. lydekkeri* Noetl.).
Conus malaccanus Hwass.

Kabat anticline.—

Nerita ? sp.
Conus malaccanus Hwass.
Pyrula bucephala Lam.
Conus literatus Linné.
Voluta dentata Sow.

Taungtha Hill.—

Spine of *Myliobates ?* Noetl.
Balanus tintinnabulum Linné.

Hills near Kwatalin, 21 miles south of Taungtha.—

Vicarya callosa Martin.
Cytherea erycina Favanne.
Scutella ? sp.

[G. DEP. COTTER.]

Some Triassic Ammonites from Baluchistan.

While looking through a collection of fossils made in Baluchistan by Kishen Singh, late Sub-Assistant, a number of ammonites embedded in a black shale were noticed. Their general appearance suggested that they were probably Triassic in age. The label with the specimens reads: "In a concretion in black shales No. 5, about 2 miles south-west of Babazai." Reference to the Museum register shows that these fossils come from the Brewery beds which are said to belong to the Dunghan group. I have not been able to find the village mentioned by Kishen Singh on any map, but reference to his maps makes it certain that these specimens come from the Brewery hill, west of Quetta, as this is the only locality where the strata No. 5 are marked. The ammonites, which are generally small and stunted forms, are crowded in a black calcareous shale. The interior of each ammonite has been replaced by calcite. The individual specimens are difficult to extract. Of those that can be got out are some very involute ammonites with a shape which recalls *Rhacophyllites Vredenburgi* described by Diener from the Triassic shales near Pishin. The difference lies in the umbilicus which is obsolete in the present specimen. The suture line being of the Phylloceratid type, this fossil must be called *Phylloceras*. At least six specimens of this fossil occur.

Some small, rather globose involute forms ornamented with smooth ribs which are not prominent show great resemblances to *Ptychites*.

A fragment of an involute ammonite ornamented by fine longitudinal ribs seems to belong to the genus *Cladiscites*. The sutures have not been seen. The other ammonites have not been identified, but they seem to be Triassic, at any rate in appearance. The presence of this probably upper Triassic deposit in the Brewery beds is probably to be accounted for by faulting, the region round Quetta being a very disturbed one.

[G. H. TIPPER.]

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MARINE FOSSILS IN THE YENANGYAUNG OIL-FIELD, UPPER BURMA. BY E. H. PASCOE, M.A., B.Sc., *Geological Survey of India*. (With Plate 18.)

SINCE the publication of a short note on this subject (*Rec. Geol. Surv. Ind.*, Vol. XXXV, Part 2, page 120), a second marine fossiliferous bed has been discovered in the Yenangyaungian or upper part of the Miocene, near Twingon. Of the two fossil horizons thus established, the more recently found one is older than that recorded in the note, and will be described first.

It occurs close to the base of what Dr. Noetling has termed the Yenangyaungian stage, in the centre of the anticline, where the strata are practically horizontal, about 1,100 feet below the Ferruginous Conglomerate or Pliocene-Miocene boundary. Its locality is the north bank of the Natsin Yo, almost due north of the village of West Twingon, close to where a large tributary enters from the north. (See 8-in. topographical map; or 4-in. geological map, *Mem. Geol. Surv. Ind.*, Vol. XXVII, Part 2.) The rock may be described as a highly impure limestone containing large quantities of sand and pebbles of clay, and is crowded with minute shells and shell fragments. Most of these lie in a horizontal position, and for this reason the rock splits more readily in this direction. Fossils extend for about 30 yards horizontally, when the limestone first becomes unfossiliferous and then dies out, the horizon becoming obscure. Here and there the margins of the rock assume the form of soft sand containing soft chalky shells, and it is evident that the limestone is a secondary one produced by the introduction of calcareous matter into a fossiliferous sand, the fossils in

fact owing their preservation to the advent of the carbonate of lime, which in fact probably originated from the fossils themselves.

The chief character of the bed is the minuteness of the shells, although nearly all of these can be identified—where identification is possible—with Miocene forms of ordinary size found at Singu, Yenangyat, Minbu, Thayetmyo, Prome, and elsewhere. The vast majority of the shells and fragments are those of Pelecypods, the commonest being *Dione protophilippinarum:* many of them shew compressional distortion. Sections under the microscope shew the rock to be crowded also with a species of *Rotalia.*

The following is a list of forms identified, most of which are figured and described in Noetling's "Fauna of the Miocene beds of Burma;"[1] the most frequently occurring are marked with an asterisk:—

**Rotalia sp.*
Twingonia (v. inf.).
Dendrophyllia sp. a.[2]
Arca theobaldi Noetl. (or *burnesi* d'Arch.).
,, *myoënsis* Noetl.
,, *bistrigata* Dunker.
Nucula alcocki Noetl.
Leda virgo K. Martin.
Cardita protovariegata Noetl.
* ,, *visquesneli* d'Arch.
Lucina neasquamosa Noetl.
Venus protoflexuosa Noetl.
,, *granosa* Sow.
**Dione protophilippinarum* Noetl.
,, *protolilacina* Reeve.
,, *dubiosa* Noetl.
,, (*? arrakanensis*) Noetl.
Tapes protolirata Noetl.
Dosinia protojuvenilis Noetl.
Corbula prototruncata Noetl.
Basilissa lorioliana Noetl.
**Solarium maximum* Phillipi.
Turritella simplex Jenkins.

1 *Palæont. Ind.*, New Ser., Vol. I, Part 3.
2 V. inf.

**Turritella acuticarinata* Dunker.
„ *lydekkeri* Noetl.
Calyptræa rugosa Noetl.
Natica obscura Sow.
* „ *gracilior* Noetl.
Sigaretus neritoideus Linné.
Oliva (*Strephona*) *rufula* Duclos.
Strioterebrum unicinctum K. Martin.
„ *sp.*
Terebrum smithi K. Martin.
Pleurotoma karenaica Noetl.
Clavatula munga ? Noetl.
Balanus tintinnabulum Linné.
Carcharias (*Prionodon*) *gangeticus* M. and H.

This list does not correspond satisfactorily with any of the zones established by Dr. Noetling: no zone is represented by as many as one-third the number of its types. The following table shews the number of species from this bed common to each zone:—

Zone of Cytherea erycina.	Zone of Aricia humerosa.	Zone of Pholas orientalis.	Zone of Parallelipipedum prototortuosum.	Zone of Arca theobaldi.	Zone of Anoplotherium birmanicum.	Zone of Paracyathus cæruleus.	Zone of Cancellaria martiniana.	Zone of Dione dubiosa.	Zone of Meiocardia metavulgaris.	Zone of Mytilus nicobaricus.	Zone of Cardita tjidamarensis.	Zone of Cyrena crawfurdi.	Uncertain.
7	7	5	17	17	3	10	12	2	9	12	0	0	2

The preponderance of species belonging to the zones of *Parallelipipedum prototortuosum* and *Arca theobaldi* is of little significance, as both these zones, and especially the former, are richer and more comprehensive than the rest.

The second fossiliferous horizon, on which the preliminary note was published, occurs on the west flank of the anticline, where the strata dip at 35° to the west-south-west, about 350—400 feet below the Ferruginous Conglomerate. The bed, which occurs on the south bank of a tributary to the Natsin Yo, 48° E. of S. from Taungnhit lon and 500 yards from that hill, could be traced for about 10 yards horizontally, after which fossils disappeared (see maps mentioned above). The shells, several of which have been crushed, are to be found, as in the Natsin Yo bed, in an impure concretionary limestone containing sand and clay pebbles, but are larger and less crowded, while the rock is harder and non-fissile. Soft chalky specimens occur in the soft sandstone immediately below and in the bed of sand and clay lenticels immediately above. The calcareous matter of this, like that of the Natsin Yo bed, is evidently secondary, being merely an incidental feature to which the organic remains owe their preservation.

The most interesting feature of this bed is the frequent occurrence of a small bean-like fossil which appears to resemble some form of Foraminifer allied to *Orbitoides* more than anything else (Plate 18, fig. 1). After careful examination by sections and microphotographs, however, the absence of any well-known form of structure precludes its being assigned with any degree of certainty to this group. As the organism, if an organism it be, is not only extremely common in this bed, but has been found in the Natsin Yo bed in a recently discovered Miocene outcrop about 20—25 miles east of Yenangyaung near Wetchok, and also in the Minbu Hills, the provisional name of *Twingonia* is here suggested for it and a description of its characters given.

The length of the test ranges from about 6 to 22 mm., the width from 5 to 11 mm., the thickness from 2 to 3·75 mm., and the ratio of length to width from 1·24 to 1·64. Like the bean it resembles, it splits readily into two plano-convex halves, which are often found separated (Plate 18, figs. 2, 3, and 4). An examination of microscopic sections shews a fibrous structure, the fibres running transversely to the primary plane of division. In the centre of each half

they are perpendicular to this plane, but towards the periphery they become more inclined towards the centre until at the edge of the test they usually become parallel to, and continuous with, the fibres of the other half (fig. 2). The fibres are not only interrupted by the primary plane of division, but frequently also by one or two secondary, slightly oblique, and somewhat ill-defined planes dividing the test into acute wedges (fig. 2). The flat internal face of any half test usually exhibits a number of fine ridges radiating from a slightly eccentric focus (fig. 4): some of these bifurcate towards the margin. The longest ridge is the most conspicuous, running parallel to the longer axis of the test (fig. 4): the adjacent ridges unite with it and are thus prevented from reaching the focus: it is possible these ridges may correspond to the series of septa in the Nummulinidæ. Good specimens shew the spaces between the ridges divided up into small chambers by thin cross-partitions: a chambered structure is also distinctly shewn in part of a microscopic section cut parallel to the primary divisional plane. In another good specimen from Minbu (fig. 5) the surface of the primary divisional plane shews a series of about eight concentric ridges which predominate over the radial and are not to be confounded with the minute cross-partitions mentioned above: it is possible that the latter may be a mineralogical accident. In section through a half test parallel to the primary divisional plane, no radiating structure is apparent, but a net-work of anastomosing lines, closely resembling what is seen in similar sections through a reticulate Nummulite, is plainly shewn (fig. 6). In some specimens a tangential structure can be distinctly made out, the test being divided by curved planes parallel to the external surface into thin shells; the broken edges of two of these shells are indicated in fig. 5. Whether the shells are truly concentric or form an involute spiral analogous to the "spiral lamella" of the Nummulites, could not be determined. In one of the larger specimens the thickness of each of these shells averaged 2 mm. The external surface of the test is slightly pitted but otherwise unornamented (figs. 1 and 16). Whether the fibres described above are part of the original structure of the test or whether they are to be attributed to subsequent mineralogical transformation is a matter for conjecture; possibly the discovery of some better preserved material in some other locality may throw more satisfactory light on this puzzling fossil.

Another extremely common occurrence in this bed is that of a rather slender species of *Dendrophyllia* too badly preserved to be compared with other forms, but different from the species mentioned by Mr. Pilgrim (*Rec. Geol. Surv. Ind.*, Vol. XXXI, Part 2, Misc. Notes, page 103) as occurring near the crest of the Singu anticline, and as being allied to *D. digitalis* Blainville. There is little doubt it is identical with the species in the Natsin Yo bed.

The following is a list of fossils obtained from this horizon :—

**Twingonia.*
**Dendrophyllia sp. a.*
**Cidaris sp. 1* (see Noetling's "Fauna of the Miocene beds of Burma") spines.
" *sp. 2* " " " "
Ostrea promensis Noetl.
" *papyracea* Noetl.
**Pecten kokenianus* Noetl.
Placenta prob. orbicularis Gray.
**Arca theobaldi* Noetl.
" *? burnesi* d'Arch.
* " *myoënsis* Noetl.
" *nannodes* K. Martin.
Leda virgo K. Martin.
**Cardita visquesneli* d'Arch.
Lucina neasquamosa Noetl.
Dione protophilippinarum Noetl.
" *arrakanensis* Noetl.
Tellina hilli Noetl.
Corbula socialis K. Martin.
Solarium maximum Phillipi.
**Turritella simplex* Jenkins.
* " *acuticarinata* Dunker.
Vermetus sp.
Natica obscura Sow.
" *gracillior* Noetl.
Galeodea monilifera Noetl.
Ficula theobaldi Noetl.
Triton (*? neocolubrinus*) Noetl.
Persona gautama Noetl.

Pyrula bucephala Lam.
Oliva rufula Duclos.
„ cf. *virginea* d'Arch.
Strioterebrum unicinctum K. Martin.
Surcula feddeni Noetl.
Conus malaccanus Hwass.
Conus galensis Noetl.
Carcharias gangeticus M. and H.
Myliobates sp. (same as figured in "Fauna of the Miocene beds of Burma").

Siluroid.

The fragments of the species of *Placenta* appear to be identical with specimens from Wetchok and Minbu, which differ in no essential character from the living *P. orbicularis*: this fossil was found by Mr. Tipper in the Andaman Islands.

From the following table shewing the number of species common to each of Dr. Noetling's zones, it will be seen that the bed approaches more closely to the zone of *Arca theobaldi* than to any other:—

Zone of Cytherea erycina.	Zone of Aricia humerosa.	Zone of Pholas orientalis.	Zone of Parallelipipedum prototortuosum.	Zone of Arca theobaldi.	Zone of Anoplotherium birmanicum.	Zone of Paracyathus cæruleus.	Zone of Cancellaria martiniana.	Zone of Dione dubiosa.	Zone of Meiocardia metavulgaris.	Zone of Mytilus nicobaricus.	Zone of Cardita tjidamarensis.	Zone of Cyrena crawfurdi.	Uncertain.
3	6	5	1	21	5	11	10	0	6	10	0	0	1

The discovery of marine fossils in two widely separated horizons confirms a suspicion which the writer has for some time held, that the Miocene beds of the Yenangyaung oil-field differ in no essential respect from what has been described as the marine type found at Singu, Yenangyat, Minbu, etc. The sediments are of the same description and selenite is no more abundant than it is at any of the outcrops of "marine" beds. With one exception only, all occurrences of the estuarine forms, *Batissa petrolei*, *B. crawfurdi*, and *B. kodaungensis*, have been found so far only in immediate proximity to the Miocene-Pliocene boundary; the exception occurs a little south of Beme village, some 300 feet below the topmost Miocene bed. In every case the occurrences are extremely local, the *Batissa* being found crowded together in small patches of a few yards in extent. It is a question worth consideration whether the Singu, Yenangyat, Minbu, and Thayetmyo type of Miocene is to be regarded as exclusively marine, or whether it may not contain a few fresh or brackish water sediments. According to the latter supposition, the Yenangyaung facies may be considered as containing a slightly greater percentage of fresh-water sediments.

EXPLANATION OF PLATE.

"*Twingonia.*"

Fig. 1.—External surface of a test. Nat. size. (Minbu.)

" 1*a*. (Do.) Side view. " " (")

" 1*b* External view of test. Enlarged 4½ times. (")

" 1*c*. (Do.) Side view. " " " (")

Fig. 2.—Transverse section of a half, shewing fibrous structure and a secondary oblique divisional plane (*p*): the upper margin represents the primary divisional plane and is missing to the right of the figure where the specimen has been fractured. Magnified 10 times. (Twingon.)

Fig. 3.—Transverse section of complete test shewing the two halves separated by the primary divisional plane (*d*), and the thickness of the test. Magnified 3 times. (Twingon.)

Fig. 4.—The inner surface of a half test shewing radial and concentric ridges: (*r*) is the longest ridge. Magnified 3½ times. (Twingon.)

Fig. 5.—The inner surface of a half test shewing more pronounced concentric ridges with less prominent radial ones. At S are the broken edges of two of the tangential shells spoken of in the text. Magnified 8 times. (Minbu.)

Fig. 6.—A section through a half test parallel to the primary divisional plane, shewing the reticulate structure. Magnified about 20 times. (Yenangyaung.)

ON THE OCCURRENCE OF FRESH-WATER SHELLS OF THE GENUS BATISSA IN THE YENANGYAUNG OIL-FIELD, UPPER BURMA. BY E. H. PASCOE, M.A., B.SC., *Geological Survey of India.* (With Plates 19 and 20.)

UP to November 1906, the only known locality from which specimens of *Batissæ* had been obtained in the Yenangyaung oil-field was that recorded by Dr. Noetling[1] as existing east of Minlindaung. The two species found were *B. crawfurdi* and *B. petrolei.* Fragmentary specimens of the large *B. kodaungensis* had also been discovered, but in what locality is not mentioned. In December 1906, three other small beds of *Batissæ* were found by the writer. The well-preserved shells are crowded together, generally in a sandy clay, and in most cases the two valves are united. Briefly the known occurrences of this genus in the oil-field are as follows:—

(1) At the head of two of the small sources of the more easterly of the two northwardly flowing tributaries immediately east of the hill known as Minlindaung (see map, *Mem. Geol. Surv. Ind.*, Vol. XXVII, Part 2), two small patches of sandy clay, containing hundreds of specimens of *B. crawfurdi* and *B. petrolei*, can be found after careful search. Whether the two beds are continuous or separate is doubtful; the exposure seen in each case extends only for a few feet horizontally. The horizon is just above the Ferruginous bed mapped by Mr. Grimes as the Miocene-Pliocene boundary bed. This is in all probability the place from which Mr. Crawfurd collected his specimens in 1829, and which Dr. Noetling rediscovered 67 years later.

(2) Half a mile north of Minlindaung, just below the eastern outcrop of the Ferruginous Conglomerate but above the soft red ferruginous bed which accompanies Grimes' White Sandstone,[2] is another patch of Batissa-bearing sandy clay. *Crawfurdi* and *petrolei* both occur: a few of the shells have been crushed.

[1] *Palæont. Ind.*, New Ser., Vol. I, Part 3, p. 29.

[2] The brilliant whiteness of this bed is due to the presence of a large percentage of kaolin

(3) By the side of the road where it passes over the hill known as Kyat lein gon, east of Kodaung, is an interesting bed of hard clayey sand crowded with specimens of the enormous *B. kodaungensis*. It occupies exactly the same horizon as that of *crawfurdi* and *petrolei*, *viz.*, just below the hard Ferruginous Conglomerate. The shells themselves are friable and the enclosing rock rather hard, so that it is impossible to extract complete specimens, but from measurements made on the spot as well as from fragments figured in the plate (Plate 19, figs. 1 and 2), the species must have been of great size. Dr. Noetling's incomplete specimen measured 75 mm. in height, but valves at Kyat lein gon frequently reach 4 inches (101·5 mm.) : one valve measured 4½ inches by 4 inches (115 mm. by 101·5 mm.). A specimen of *kodaungensis* found near the Miocene-Pliocene boundary in the Minbu Hills is for the sake of convenience figured in this paper (Plate 20, fig. 2). Unfortunately most of the test fell away during extraction, but from the cast the length was more than 170 mm. and probably fell little short of 200 mm.

Neither *crawfurdi* nor *petrolei* were to be seen in this bed, but a small unidentifiable Gastropod was found. It is possible Dr. Noetling's specimens came from this spot.

(4) About a mile south of Beme village on the north bank of the Yedwin aing Yo, some 300 feet below the Ferruginous Conglomerate on the western flank of the anticline, is a small patch of dark earthy limestone crowded with a new form of *Batissa* which may be regarded as a variety of *B. crawfurdi* and which I have named *yedwinensis*. Shells consisting almost always of united valves can be picked up loose, having been liberated by the weathering of the limestone (see Plate 19, figs. 3-5 ; Plate 20, figs. 1-1*c*). Besides this new form, both *crawfurdi* s. str. and *petrolei* occur occasionally. The most noticeable feature is the crushing to which nearly every shell has been subjected, and for this reason the true shape of the variety *yedwinensis* is more or less a matter of surmise : measurements, except in a few cases, would therefore be unreliable. The effect of the compression has been to diminish the height and therefore to increase the ratio L/H. Even allowing for distortion, this index is greater in *yedwinensis* than it is in *petrolei*. In the former it often rises to 1·35, while in the latter it ranges from 1·00 to 1·27. The thickness (from valve to valve) is the

same as in the ordinary *crawfurdi* (Plate 19, fig. 4, and Plate 20, figs. 1*b*, 1*c*).

The umbo in the new form, when preserved, is either equidistant from the anterior and posterior margins, or slightly anterior, and is strongly inflated, slightly more so than in *crawfurdi* s. str. The ornamentation is the same as that of the latter,[1] and another resemblance between the two lies in the great thickness of the test, which attains 5 mm. in average specimens. The dorso-posterior portion of the shell is ventricose and forms a broad obscure ridge extending from the umbo to the ventro-posterior margin. The anterior margin is rounded, passing gradually into the long, almost straight ventral margin, which again passes somewhat abruptly into the posterior margin: this is at first rounded, but becomes straight before joining the strongly curved cardinal margin (Plate 20, figs. 1 and 1*a*).

In the Yedwin aing Yo bed one or two isolated shells, which could be classed under none of the described forms, were found: whether these are to be regarded as distinct species or varieties, or as mere pathological specimens, further research must decide. One of them is illustrated in Plate 19, figs. 5 and 5*a*.

The occurrence of *Batissæ* so low down in the Miocene as in the case of the Yedwin aing Yo bed is significant. There is little doubt that the Miocene water around Yenangyaung was shallower than it was at Singu, Yenangyat, and other places. Numerous local unconformities as well as excessive current-bedding bear witness to this. This bed evidently represents some premature local establishment of transient fresh-water or estuarine conditions. At the close of the Miocene period, estuarine conditions became general and Batissa-bearing beds more frequent.

EXPLANATION OF PLATE 19.

Fig. 1.—*Batissa kodaungensis* Noetl. Fragment of valve. Nat. size. (Kyat lein gon, Yenangyaung.)

Fig. 2.—Ditto.

Fig. 3.—Ditto. Left valve. Nat. size. (Near Beme.)

Fig. 4.—Ditto. Dorsal aspect of united valves. Nat. size. (Near Beme.)

Fig. 5.—New variety or pathological specimen. Left valve. Nat. size. (Near Beme.)

Fig. 5*a*.—Ditto. Anterior aspect of united valves. Nat. size. (Near Beme.)

[1] *Palæont. Ind.*, New Ser., Vol. I, Part 3, p. 184.

EXPLANATION OF PLATE 20.

Fig. 1.—*Batissa crawfurdi* var. nov. *yedwinensis*. Right valve. Nat. size. (Near Beme.)

Fig. 1*a*.—Ditto. Left valve. Nat size. (Near Beme.)

Fig. 1*b*.—Ditto. Anterior aspect of united valves. Nat. size. (Near Beme.)

Fig. 1*c*.—Ditto. Posterior view of united valves. Nat. size. (Near Beme.)

Fig. 2.—*Batissa kodaungensis*. Cast of right valve with a little shell still adhering. Nat. size. (Minbu Hills, immediately N. of Palanyon.)

ON A NEW SPECIES OF DENDROPHYLLIA FROM THE UPPER MIOCENE OF BURMA. BY E. H. PASCOE, M.A., B.SC., AND G. DE P. COTTER, B.A., F.G.S., *Assistant Superintendents, Geological Survey of India.* (With Plate 21.)

IN January and February 1907, specimens of a new species of *Dendrophyllia* were obtained from limestones in the Singu oil-field, and in the Minbu Hills. The Singu bed, averaging about 6 inches in thickness, contains few other fossils besides this coral, and is evidently the remains of a small reef. The following are the principal characters of the species which we have named *Dendrophyllia macroriana.* The corallum ranges usually from about 10 to 20 mm. in diameter and is occasionally larger. The calices are frequent and close together, and project from the surface of the corallum. The pseudo-columella is spongiose, large but ill-defined. The number and arrangement of the septa are somewhat irregular (Pl. 21, fig. 3), but some of the smaller ones unite with the larger in the way typical of the genus. The theca formed by the thickening of the septal edges is well developed, consisting of a spongy tissue of dissepimental cells. Externally the septa are produced to form costæ, which vary in number from 30 to 40: these are strong, well marked, slightly sinuous, granulated, and connected each with its neighbour by minute transverse processes. The costæ of each calix are separated from those of each adjacent calix by a well-developed transverse ridge: these ridges divide the surface of the coral into polygonal areas, each area enclosing a calix with its system of costæ (see Pl. 21, figs. 1, 4).

This coral resembles *D. digitalis* Blainville[1] which occurs both at Singu[2] and in the Minbu Hills, but differs from it in the following points:—

(1) The calices project from the corallum, while in *digitalis* they are depressed.

[1] See Michelin, Iconographie Zoophytique, p. 52.

[2] See *Rec. Geol. Surv. Ind.*, Vol. XXI, Part 2, p. 103.

(2) The costæ in *macroriana* are basally divided from those of the adjoining corallites by transverse ridges forming polygonal areas.

At Minbu this coral is found at some distance from the crest, just north of Taukshabin, lat. 20° 9′; long. 94° 56′, and is associated with an assemblage of fossils which coincides fairly well with the zone of *Cancellaria martiniana:* whether it is confined to this zone or not is a matter which the future will decide.

EXPLANATION OF PLATE.

Fig. 1.—*Dendrophyllia macroriana,* natural size.

Fig. 2.—*Dendrophyllia macroriana,* nat. size, with calix ground and polished to show internal structure.

Fig. 3.—*Dendrophyllia macroriana,* calix ground and polished showing arrangement of septa: from a microphotograph enlarging about 8 diameters.

Fig. 4.—*Dendrophyllia macroriana,* showing costæ of adjacent corallites separated by transverse ridges: enlarged about 3 diameters.

THE STRUCTURE AND AGE OF THE TAUNGTHA HILLS, MYINGYAN DISTRICT, UPPER BURMA. BY G. DE P. COTTER, B.A., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 22 and 23.)

INTRODUCTION.

THE range of hills culminating in Taungtha Hill which I visited in March 1907 (Lat. 21° 18′; Long. 95° 30′) is about six miles in length, extending in a direction N. N. W.—S. S. E. Taungtha Hill, the highest point of the range (1,788 ft.) is a landmark only inferior to Mount Popa, and can be seen from a great distance owing to the flatness of the surrounding country. The level plains around are more or less covered by alluvium, and the water-courses are marked by plantations of toddy palms (*Borassus flabellifer*). The Taungtha Hill range is covered by thick and thorny scrub jungle, and is included in the area of reserved forests.

Structure.

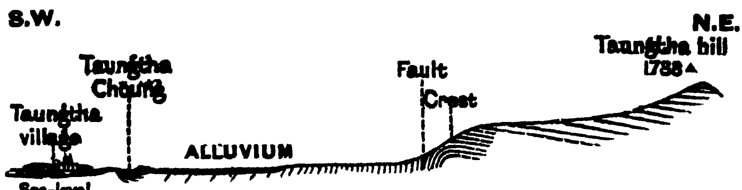
On the top of Taungtha Hill the strata appear to be almost horizontal with perhaps a slight easterly dip, but the exposures are very poor. The sandstone is of a coarse massive type, and its bedding planes are vague. On the flanks of Taungtha Hill the dips radiate outwards from the summit, being very steep on the W. S. W. and E. N. E. sides of the hill, and gentle to the N. N. W. and S. S. E. The structure is therefore a flat-topped elliptical dome whose long axis appears to run in a direction roughly 30° W. of N. A somewhat similar dome-structure characterises the most northerly hill of the range which is marked on the map by the two triangulated points 1,263 ft. and 1,315 ft. Between these two domes the intervening hills show great confusion of strata and such dips as were obtainable seemed to point to a saddle-structure between the two domes, but the constant change of direction and angle of dip shows that this is complicated to a great extent by minor folding and very possibly faulting.

The anticline, the extremities of which rise to form these two domes, is an asymmetric one, its axis running in a general direction 30° W. of N. In the north of the area the asymmetry is best seen, the strata dipping very steeply on the west side of the range and gently on the east.

Near Taungtha Hill in the south, the dips are never persistent over a large area, and exposures which are more distant from the hills show a more gentle angle of dip.

Although I was unable to obtain reliable dips upon Taungtha Hill, there seems reason to believe that the folding here also is asymmetric. From a distance the strata which form the flat top of the dome appear horizontal. But in a stream-bed running from the hill due west towards Uyin, the section shows a distinct crest: on the hill-side the beds dip 11° due east, and moving west, we find them becoming level and then dipping west with gradually increasing angles till vertical strata are reached striking to 26° W. of N.

Mr. Pascoe in an unpublished note, describing a traverse from Taungtha village to the hill-top, says:—"Proceeding up the steep dip-slope of the main-hill, the dip becomes less, gradually at first, but rapidly as we approach the top of a broad W. N. W.—E. S. E. ridge flanking the hill on this side. As far as could be made out, this broad ridge forms the crest of the anticline. I saw dips on the other side which I estimated at about 20°." The dome is asymmetrical, the crest apparently lying west of the summit of Taungtha Hill and close to the western scarp. The direction of the crest here I estimate at about 30° W. of N.



Scale, horizontal 2″ = 1 mile, vertical ⅛″ = 100 feet.

Faults.

It is evident that such a structure as above described could not exist without serious faulting. There is reason to suppose that there

is a strike-fault skirting the west base of Taungtha Hill, in a direction 40° W. of N. The line of probable faulting is marked by abundance of boulders, the strata are vertical and are much broken and disturbed, and the dip rapidly becomes gentle on either side. Two unimportant minor faults could not be traced across this line of probable faulting. The down-throw, judging by the hade of the strata, is to the west. In the south-east of Taungtha Hill in the Magyibinde Chaung, a section shows a very considerable fault. The width of the fault-rock is over ¼ mile. Plate 22 shows the faulting at the west end of the section. The fault strikes 20° W. of N., and can be traced within ¼ mile of the foot of the hill, but close to the hill, the structure of the strata is concealed by scree, and such exposures as I saw did not enable me to trace the fault further northwards.

Another faulted area bounds Taungtha Hill on its east side, and is marked by vertical strata which rapidly change on either side of the fault line to gently dipping strata. Its general direction is about 35° W. of N., but since the strike of the vertical strata varies within about 12° on either side it is possible that there is more than one fault. The down-throw is to the east.

I failed to trace this fault southwards so as to meet the fault to the south-east of the hill, which strikes 20° W. of N. It is possible that they meet in the valley between "860 ft." hill and Taungtha Hill.

Again in the Magyibinde Chaung, due east of "860 ft." hill, steeply dipping fault rock is seen striking 25° N. of W. and hading to the north.

To the north of the area, an interesting section, on the Taungtha-Myingyan road south of "1,315 ft." hill, shows towards the west shales dipping gently westward, and somewhat contorted. Proceeding east, fault rock is seen; the strata are upturned and much broken. To the east of this fault the strata recover their gentle westward dip. The beds rise gradually to a crest as we proceed east. The section shows that the crest, which is really the production of the major axis of the elliptical dome structure of "1,315 ft." hill, is seriously faulted, and the vertical strata of the fault-rock strike to 40° W. of N.

Beyond this second fault the strata dip gently eastward. Other faults in this area have been marked on the accompanying map.

Although the thickness of the jungle prevented me from tracing these faults beyond a short distance, it seems evident that the northern part of the hill-range is seriously disturbed and faulted.

Contortion.

Many instances of great contortion indicate the high degree of pressure to which the rocks of these hills were subjected, probably in post-Pliocene times. Fragments of clay-rock metamorphosed into schistose phyllites showing pressure-wrinkles were obtained from the slopes of Taungtha Hill; in one specimen the laminæ have been bent into an arc. Warping of the shale beds was observed in many localities.

It is remarkable that the anticlinal crests at Yenangyat and Minbu have a direction 19° W. of N. while those of Yenangyaung and Taungtha are about 30° W. of N. It will be interesting in future investigations of other anticlines of the Burma oil-belt, to decide whether their crests run in either of these two general directions.

Lithology.

The rocks are a series of alternating sandstones and clay beds with occasional slabs of limestone, and on the whole the sandstones predominate. Red ferruginous conglomeratic bands crop out close to the S. W. base of Taungtha Hill, and in one exposure the conglomerate is seen to contain abundant selenite. I am uncertain whether these bands are to be correlated with the Ferruginous Conglomerate horizon in the Yenangyaung and Yenangyat-Singu anticlines; I have not observed selenite in the beds overlying these bands, and it is possible that they belong to the uppermost zones of the Yenangyaungian series. Apart from bands of true conglomerate, beds of red earth and brick-like bands crop out around the southern foot of the hill-range, from near Thapanbino to "860 ft." hill. Similar beds are exposed on "678 ft." hill near Mingan. It is remarkable that small fragments of silicified wood are found lying on the surface of these beds; such fragments are not however very common. I have found similar specimens on the lower slopes of Taungtha Hill, where I think there is no doubt that the rocks are of Miocene age. It seems therefore unwise to attach too much weight to their presence. It is to be

observed that the silicified fragments found close to the base of the hills were all small, being rarely more than 3 inches in length.

The occurrence of these fragments at fairly high levels above the present limit of alluvial deposits can be explained by supposing the alluvium to have once extended to a high level, and to have been subsequently denuded. In support of this view, it is to be observed that the fragments of silicified wood found on the hill-slopes and close to the base of the hills were all small fragments, usually about 3 or 4 inches in length. Two blocks of granitic gneiss were also found on the hill-slopes, one specimen being water-worn; and these may well have been carried by water action to the hills. Mr. Pascoe notes a similar occurrence at Kabat (Records, Geological Survey of India, Vol. XXXIV, page 249).

The exposures on Taungtha Hill show a coarse micaceous sandstone with large spherical concretions. I have observed traces of brown carbonised wood on the fresh fracture-surfaces of some specimens. The sandstone is massive and its bedding-planes very vague. It immediately underlies the beds of red earth alternating with sandstone described above.

North of Taungtha Hill several sections show blue selenite-bearing shales and well-bedded olive fine-grained sandstones of a typical Upper Miocene appearance. Current bedding and ripple-marks in sandstones were seen to the south of the hills. That the Miocene extends northwards to at least ¾ mile N. of Gwebinyo is shown by an exposure at this spot of ferruginous beds containing selenite, which may possibly be its upper boundary.

Age of rocks.—The general aspect of the rocks, the presence of selenite, and the occurrence of marine fossils indicate the rocks to be of Upper Miocene age. Although the evidence is somewhat meagre, I think it probable that the lower Miocene is not exposed here. Selenite, which is found in some of the lowest beds, is characteristic of the Upper Miocene at Yenangyaung.

The boundary of the Pliocene and Miocene is very difficult to fix in this area. Fossil-wood, except when *in situ*, cannot be regarded as good evidence of Pliocene age. Selenite is known to occur in Pliocene strata at Yenangyat, but never in large quantity, and I have regarded the horizon at which it dies out as the boundary here in the absence of other evidence. Ferruginous beds such as are found

to the S. W. of Taungtha are characteristic of the beds immediately above and below the Pliocene-Miocene boundary.

Thus for two exposures S. W. of Taungtha Hill and N. E. of the village the evidences of Pliocene age have been as follows :—

(1) They lie immediately above selenite-bearing beds of ferruginous conglomerate and ferruginous earth, and no selenite was found in the exposures themselves.

(2) The beds exposed in the stream bed are bedded sandstones with ochreous staining, and contain a network of irregular veins of calcareous matter described by Mr. Pascoe (Records, Geological Survey of India, Vol. XXXIV, page 248). These are more characteristic of Pliocene than of Miocene strata.

On the whole the evidence available in determining the boundary has been usually extremely scanty. The railway-cutting ¾ mile S. of Taungtha station shows well-bedded greenish buff sandstones alternating with pale bluish shales. The rocks are evenly stratified and current bedding is absent.

Fossils.—Marine fossils were found in two localities :—

(1) On a small hillock at the S. foot of Taungtha Hill a fragment of *Turritella* was found.

(2) Close to Gwebinyo village north of the hills a fossiliferous limestone containing clay pebbles and crowded with fragments of pelecypods and gastropods was found, but the fossils were too fragmentary to admit of identification. The following genera have been doubtfully identified :—

Ostrea
Pyrula
Turritella

A simple hexacorallid coral, possibly *Ceratotrochus*.

Markings of probable organic origin and resembling leaf-markings were found ¼ mile N. E. of Thapanbin on the weathered surface of a white calcareous clay. Besides these the only fossils found in this area were the carbonised wood in sandstone, and the fragments of silicified fossil-wood mentioned above. One specimen of silicified wood shows the structure of Palm-wood, the fibro-vascular bundles crossing one another in the manner characteristic of monocotyledonous wood (*Palmoxylon, Schenk.*).

Prospects of Oil.

The prospects of oil in these hills appear to me to be very poor, for the following reasons :—

(1) Yenangyat, which may be taken as one of the nearest points of the known oil-belt, is about 44 miles distant from Taungtha. Although the width of the oil-belt is at present a matter of question, it is still doubtful that it extends so far east as Taungtha.[1]

(2) The whole hill-range is, as has been shown, seriously faulted; and the only place where, as I think, drilling could be made with the slightest hope of success is a little to the east of the crest of the Taungtha Hill dome, described above. Even here, contortion and faulting is found close to the crest, and the chances seem almost hopeless.

(3) There are no surface indications of oil at Taungtha.

(4) The rigging of drilling machinery upon Taungtha Hill would be a matter of considerable expense and difficulty. It would also be necessary always to drill from the level of the hill-scarp to the level of the plain at the base of the hills, in strata obviously unpetroliferous.

On the whole, it seems safe to say that these hills are not worth testing. If oil is found in paying quantities at Kabat, objection (1) will be in great part disqualified, but the faulting and contortion of the area would render the existence of petroliferous sands questionable even were Taungtha situated in the centre of the known oil-belt.

[1] See *Rec. Geol. Surv. Ind.*, XXXI, p. 251.

NOTE ON SOME FOSSILS FROM THE SEDIMENTARY ROCKS OF OMAN (ARABIA). BY PROFESSOR C. DIENER, *Vienna*. (With Plate 24.)

IN the year 1906 Mr. T. H. Holland, Director of the Geological Survey of India, offered me the opportunity of examining a small collection of fossils from the sedimentary rocks of Oman. In this collection were contained 32 specimens from Elphinstone inlet, which had been collected in 1872 by W. T. Blanford and considered to be of probably triassic age by F. Stoliczka, and 39 specimens of anthracolithic Brachiopoda, Bryozoa and Anthozoa from the Wadi Adi (6 miles west of Muscat), which had been collected by Mr. G. E. Pilgrim in 1905. Although my examination of these fossils has not led to any particularly new or unexpected results, a short note will be found useful, because it refers to a region whose geological structure is as yet very imperfectly known.

The materials from the two localities mentioned above are certainly of widely different age and will therefore be treated separately.

I.—Fossils from Elphinstone inlet (coll. W. T. Blanford).

The fossils collected by W. T. Blanford and mentioned in his report (*Rec. Geol. Surv. Ind.*, 1872, Vol. V, p. 75) were found in a dark grey limestone, near Elphinstone inlet, peninsula of Masenderam, at the entrance to the Persian Gulf (26° 12′; 56° 23′). They were submitted for examination to F. Stoliczka, who suggested their triassic age, judging from the affinity of several examples of *Myophoria* to the Alpine *Myophoria chenopus* Lbe. from St. Cassian. Together with them, however, a species of *Exogyra* was noticed by Stoliczka, belonging to a type unknown in triassic beds.

Stoliczka's short note (l. c. p 76) is all what is known about Blanford's materials. Neither detailed descriptions nor illustrations of the fossils have as yet been published.

MYOPHORIA OMANICA nov. sp. Figs. 1, 2, 3.

This species is represented by numerous single valves, which are never found in their original position connected by the ligament,

but invariably occur separated. Both right and left valves are known to me, but it is of course impossible to decide whether or not the complete shell was slightly inequivalve. Some slabs of rock consisting of a true lumachelle of valves remind us strongly of rock-specimens from the Toren beds in the south-eastern Alps, which are entirely composed of detached valves of *Myophoria Whatelyæ* v. Buch.

The shell is ovately trigonal in outline and moderately convex. The umbones are shifted considerably towards the anterior end, faintly developed and mesogyrate. The majority of left valves seem to be curved a little more strongly than the right ones. The number of radiating ribs in front of the marginal carina is from seven to eight. The ribs are stout, well elevated, broadly rounded above and intersected by very numerous concentric striæ of growth. The marginal carina extending from the umbo backward and downward to the basal margin is higher and stouter than the ribs, and separated from the first rib by an antecarinal depression which is broader than the intercostal valleys. In this character it recalls *Myophoria vestita* Alberti (Ueberblick ueben die Trias, 1864, p. 113, Tab. II, fig. 6). The posterior area has no distinct radial ribbing, but is covered with very numerous and delicate concentric striæ.

Escutcheon small, indistinctly defined, separated from the area by a geniculation in the general slope of the shell, not by a distinct rib. The small, cordiform lunula in front of the foremost rib is distinctly convex, not excavated.

That this species is, indeed, a typical *Myophoria* is shown not only by its ornamentation, but also by the development of its hinge. I have succeeded in clearing the hinge of a left valve from the adjoining matrix. This hinge shows a very robust, triangular, central tooth, which is not divided by a median groove. The anterior lateral tooth is situated very close to the hinge margin, elevated into a rounded crest and enlarging slightly in the direction towards the umbo. Posterior lateral tooth united with the hinge margin, not individualised. Teeth not striated. The posterior groove is very narrow and united with the larger, triangular anterior groove in front of the umbo.

The shelly substance is very thin, as is obvious from a fragment of the test, which has been preserved in the example illustrated in fig. 2.

The present species has been compared to *Myophoria chenopus* Laube (Fauna der Schichten von St. Cassian, Denkschr. Kais. Akad. d. Wissensch. Wien, math. nat. Kl., 1865, p. 58, Taf XVIII, fig. 4) by Stoliczka, but it seems to be allied still more nearly to *M. inæquicostata* v. Klipstein (Beitræge zur geologischen Kenntnis der oestlichen Alpen, p. 254, Taf. XVI, fig. 18), which is distinguished from *M. chenopus* by having the ribs straight and rounded above, not acute.

In their external shape and dimensions *Myophoria omanica* and *M. inæquicostata* do not differ considerably. Among the examples of the latter species, which have been illustrated by Bittner (Lamellibranchiaten der alpinen Trias, I. Revision der Lamellibranchiaten von St. Cassian, Abhandl. K. K. Geol. Reichsanst, XVIII Bd., p., Taf. XI, figs. 1-14), it is especially the large type from the Toren beds of Raibl which might put in a claim for a closer comparison. The width of the antecarinal depression in *M. omanica* is no distinctive character of paramount importance, as in some varieties of *M. inæquicostata* from the Cardita beds of northern Tirol, the antecarinal depression is also broader than the intercostal valleys. There is, however, another remarkable feature of distinction in the sculpture of the two species, and this is the irregularity of strength in the ribs of *M. inæquicostata*. In this species the marginal carina and two or three preceding ribs are the strongest, whereas in our Arabian form this difference in the development of ribs has not been noticed. There are also some differences in the shape of the area, which is radially depressed, and of the broadly lanceolate escutcheon, which is equally depressed in *M. inæquicostata*.

The outlines of the two species appear to differ considerably, if the large specimen of *M. omanica* illustrated in fig. 1, is taken as prototype of the Arabian species. But this specimen is somewhat distorted and deformed. If we try to reconstruct the outlines of the specimens preserved in the slab of rock, which has been illustrated in fig. 3, they seem to agree pretty well with some of Bittner's illustrations. It is worth noticing the statement of this eminent author, that neither v. Klipstein's nor v. Hauer's nor Laube's illustrations of *Myophoria inæquicostata* give an exact side of the shape of this species.

The differences enumerated above are certainly sufficient to

distinguish the two species, but otherwise their very close affinity cannot be denied.

EXOGYRA sp. ind. aff. CONICA d'Orb. Fig. 4.

A single right valve of an *Exogyra*, which has been compared to *E. conica* d'Orbigny. It is, indeed, this species of middle cretaceous age to which it seems to be most nearly allied. Among the specimens illustrated in Coquand's "Monographie du genre Ostrea" (Marseilles, 1869) it agrees best with the small example illustrated in Pl. LIII, fig. 4. It is strongly convex and divided into two halves of nearly equal size by an angular ridge, which is marked very distinctly in the apical region, but becomes flattened gradually towards the ventral margin of the shell. The beak is twisted spirally very strongly.

Sculpture nearly reticulate, concentric wrinkles intersecting numerous ribs, which are directed obliquely. The ribbing is stronger than in the majority of examples of *Exogyra conica*.

This valve of a typical *Exogyra* of cretaceous affinities occurs on a slab of rock together with numerous casts of undeterminable bivalves of very different shapes and with the ventral valve of a brachiopod, recalling *Terebratula* or *Waldheimia*.

II.—Fossils from the Wadi Adi, 6 miles south-west of Muscat (coll. G. E. Pilgrim).

In the great mass of siliceous limestones of the "Oman series" forming the backbone of the mountain range, which runs in a general S. E.—N. W. direction from Jebel Jaalan at the Ras el Hadd corner of Arabia to the base of the Massandim peninsula fossils were found by Mr. G. E. Pilgrim in two bands in the Wadi Adi, some six miles south-west of Muscat. One of those two bands consisted of a black, compact limestone and contained corals and silicified brachiopods. The other was of a paler colour tinged with red, containing numerous brachiopods, especially of the genus *Productus* with *Orthoceras* and encrinites. Interbedded were some thin layers of a yellow, slaty shale, containing *Bryosoa*. The general character of this fauna was considered by its discoverer as indicative of

anthracolithic age "corresponding perhaps to the middle Productus limestone of the Salt Range."

The majority of the fossils are in a very bad state of preservation. Some slabs of rock are made up almost entirely of the shells of a small *Spirigera* or *Spirigerella* with a strong median septum in the ventral valve, but it is impossible to determine the species. Among the class of Bryozoa *Fenestella* is probably represented, whereas the presence of other genera is rather doubtful. A small rock-specimen contains sections recalling *Syringopora* or *Aulopora*. A second one of larger dimensions consists of some cylindrical or dendroid coralla, belonging perhaps to the family of *Monteculiporidæ*. As a satisfactory examination of these remains is rendered impossible by their state of preservation, I have deemed it preferable to abstain from an approximate identification of such specimens as are unfit for description or illustration. In fig. 8 a slab of rock is represented containing remains of *Fenestella* and of a cylindrical coral recalling *Stenopora columnaris* Schloth. from the permian zechstein.

PRODUCTUS cf. INDICUS Waagen. Figs. 5-6.

1884. *Productus indicus* Waagen, Salt Range Fossils, Palæont. Indica, ser. XIII, Vol. I. Productus limest. Foss. p. 687, Pls. LXX, LXXI, fig. 1.

Five fragmentary casts of ventral valves are available for examination. None of them is well preserved, but from a combination of their characters a fairly good idea of their shape and sculpture can be formed. They certainly belong to the group of *Productus costatus* Sow., but it is not possible to arrive at a safe determination of the species. In their characters of distinction they seem to agree best with *Productus indicus* Waag., but the differences between this species and *P. subcostatus* Waag. are so insignificant that it is rather difficult to distinguish the two forms, if one is not dealing with typical examples which have been found in a satisfactory state of preservation.

The valves are of moderate size, agreeing in this respect with the specimen illustrated by Waagen on Pl. LXX, fig. 3. They are strongly but irregularly convex, the apical region of the shell being distinctly flattened. There is a distinct sinus in the middle extending from the front to the vicinity of the apex. The dorsal valve, which

in all my specimens is covered by the rocky matrix, follows the direction of the ventral one and is strongly concave, as is obvious from sections of the two valves in weathered examples. The commencement of the trail is indicated by an obtuse geniculation. The wings have been broken off in all my specimens.

The sculpture agrees more closely with the ornamentation in *Productus indicus* than in *P. subcostatus.* The radial ribs are of irregular strength, although the irregularity is marked somewhat less strongly than in typical examples of *P. indicus.* No prominent ribs have been noticed in the region bordering the broken off wings. The regular concentric folds extend over a space of 30 to 35 mm. from the apex.

Impressions of spines are distributed irregularly and in small number over the surface of my casts. In one of my specimens a long, erect spine has been noticed rising near the border of the radial and reticulate patterns of sculpture.

HEMIPTYCHINA cf. SPARSIPLICATA Waag. Fig. 7.

1882. *Hemiptychina sparsiplicata* Waagen, Salt Range Foss., Palæont. Ind., ser. XIII, Vol. I, Productus limest. Foss. p. 366, pl. XXVII, figs. 4-6.

1892. *Terebratula himalayensis var. sparsiplicata* Rothpletz, Die Perm-Trias- und Juraformation an Timor und Botti, Palæontographica, Vol. XXXIX, p. 85, Pl. X, fig. 10.

1897. *Hemiptychina sparsiplicata* Diener, Himal. Foss., Palæont. Indica, Vol. I, Pt. 3, Permocarb. fauna of Chitichun No. I, p. 76, Pl. XII, figs. 1, 2.

A fairly well preserved cast of a representative of *Terebratulidæ* must, according to its external shape, be grouped either with *Hemiptychina* Waagen or with *Dielasma* King. As an examination of its apical region did not lead to the discovery of any traces of dental plates in the ventral valve, I have decided in favour of an identification with *Hemiptychina.*

My specimen is of an elongately oval shape, with moderately inflated valves and with a comparatively small apical angle. The front line having been injured by weathering, traces of marginal indentations are but indistinctly developed. The specimen might therefore perhaps with equal reason be referred to *Hemiptychina sublævis* Waag., the two species being linked together by a number of transitional forms.

LONSDALEIA sp. ind.

Some slabs of a black limestone are rather rich in sections of cylindrical, straight corallites reaching a diameter of 5 to 8 mm. They stand rather far apart from each other, being united only at the places where one takes its origin from the other by germination. The internal structure of the corallites has been destroyed so completely that no details can be seen in thin sections. On the weathered surface of the rock the calices show numerous septa, alternately long and short, radiating from a large central columella. The columella is comparatively thick, occupying about one-third of the diameter of the entire calix. Traces of dissepimenta have been noticed. The periphery of the corallite is formed by a distinct though thin external wall.

As far as we are able to judge from our insufficient materials, this coral might be referred to the group of *Lonsdaleia indica* Waagen et Wentzel (Salt Range Foss. Palæont. Ind., ser. XIII, Vol. I, p. 897).

SUMMARY.

As has been suggested by Mr. G. E. Pilgrim, the fossils from the Wadi Adi are indicative of an anthracolithic age, corresponding probably to the anthracolithic horizon which has been discovered by J. Morgan's expedition in Persia,[1] or to one of the horizons of the Salt Range Productus limestone.

The fossils collected by Mr. Blanford in the rocks near Elphinstone inlet exhibit rather conflicting characters. The leading fossil, a typical *Myophoria*, belongs to a group of forms which has been found up to the present exclusively in triassic beds. A species of *Exogyra*, nearly allied to *E. conica* d'Orb. which does not, however, occur together with *Myophoria omanica*, points to a younger age (probably lower cretaceous). True *Exogyræ* have as yet never been noticed in triassic strata.

It is difficult to give a decided opinion as to the stratigraphical horizon of the limestone from Elphinstone inlet, considering the scarcity of fossil remains, but there is some probability of its representing several mesozoic horizons of different age, *Myophoria* indicating a triassic, *Exogyra* a jurassic or cretaceous age for some of the beds.

[1] *J. Morgan*, Mission scientifique en Perse, Etudes géologiques, Ptie. IV. Mollusques foss., par H. Douvillé, Paris, 1904.

EXPLANATION OF PLATE.

Fig. 1 *a, b, c, d.*—*Myophoria omanica.* Left valve of a large specimen, showing the hinge-teeth.

Figs. 2, 3.—*Myophoria omanica.*

Fig. 4.—*Exogyra sp. ind. aff. conica* d'Orb.

All these specimens from Elphinstone inlet (coll. Blanford).

Fig. 5 *a, b.*
Fig. 6 *a, b.* } —*Productus cf. indicus* Waag.

Fig. 7 *a, b, c.*—*Hemiptychina cf. sparsiplicata* Waag.

Fig. 8.—Rock-specimen with casts of *Fenestella* and *Stenopora* (?).

All these specimens from the anthracolithic series of the Wadi Adi (coll. Pilgrim).

RUBIES IN THE KACHIN HILLS, UPPER BURMA. BY DR. A. W. G. BLEECK, MUNICH.

WORKS OF REFERENCE.

(1) C. Barrington Brown and J. W. Judd. The rubies of Burma and associated minerals: their mode of occurrence, origin, and metamorphosis. A contribution to the history of corundum. (*Phil. Trans. Roy. Soc. Lond.*, Vol. 187, 1896.

(2) Max Bauer, Ueber das Vorkommen der Rubine in Burma. (*Neues. Jahrb. fur Min., Geol., und Pal., Jahrg*, 1896, Bd. II.)

IN the Jade-mines subdivision of the Myitkyina district, Upper Burma, a ruby-tract is known to exist. Numerous mining-leases have been granted in this area, the fact being evidenced by countless pits, which now lie deserted and overgrown by dense jungle. Most of these old ruby-mines are in the immediate neighbourhood of Naniazeik, a village 12 miles west of Kamaing, the subdivisional head-quarters. Deserted ruby-pits are also reported from a locality 13 miles north-west of Naniazeik. Several valuable stones are said to have been found in this ruby-tract, but rubies are certainly not plentiful and consequently the returns have been profitless. Ruby-mining at Naniazeik has stopped entirely.

Another locality in which corundum has been found is situated in the hills west of the Indaw chaung about 4 miles north of the village Manwe. Here Kachins wash for corundum in the bed of a little hill-stream. The output however is insignificant. Very little is known up to date of these three occurrences of rubies, two of which I had occasion to visit during my recent tour in Upper Burma, *viz.*, the corundum-washings near Manwe and the old ruby-mines at Naniazeik.

The geological features of the country between Manwe and Naniazeik are of a simple nature, the mountain ranges between these two villages consisting only of *granite* and *marble*. The granite is a granite proper with both light and dark mica, fine-grained in texture and showing numerous concretionary patches, in which the more basic minerals have segregated during consolidation. In some places this granite assumes a foliated piezo-crystalline character

which is generally termed "gneissose." Numerous veins of *aplite* and *pegmatite* traverse the granite, the pegmatite often exhibiting the structure known as Graphic-granite. This granite envelopes large lenticular masses of *marble*, several outcrops of which were studied *in situ*. At the foot of the range of hills the alluvial soil consists of the detritus of both granite and marble. This detritus is called "*byon*" wherever it is rich in rubies.

East of the Indaw chaung the hill consists of basic eruptive rocks, of *serpentine* and *saussurite-gabbro*, which are of no interest whatever in connection with the granite and marble on the other side of the river.

A collection of specimens consisting both of granite and marble as well as river gravel and the alluvial soil called *byon* were carefully examined by Mr. I. Tanatar and myself with results as follows:—

Granite, aplite, and pegmatite.—The megascopic structure is that of a normal holocrystalline fine-grained granite. The pegmatites are often very coarse-grained and are generally developed as Graphic-granite. The aplites are of a very light colour and small grain. The constituent minerals of the normal granite are quartz and felspar, both orthoclase and oligoclase, frequently intergrown and thus resulting in a structure known as microperthite. Both varieties of mica, biotite and muscovite, are present as well as accessory minerals such as zircon and rutile. The aplites consist of a finely crystalline aggregate of quartz and felspar and very little muscovite. In one case numerous large dark metallic crystals of hornblende were observed. The mineral composition of the pegmatites is of a very acid character, quartz and felspar alone being the constituents. Schorl, titanite, and apatite are contained in minute quantities in all three species of eruptive rock.

Gneissose rocks.—In the bed of a little stream near Manwe several fragments of rock were found of undoubtedly metamorphic character. Their structure is schistose, thin layers of crystalline limestone alternating with layers of gneiss. Most of the constituent minerals can be discerned with the naked eye. They are quartz felspar, biotite, carbonate of lime, and numerous little red garnets. The latter are restricted to the layers of crystalline limestone. The microscope reveals the presence of several other minerals such as chlorite, muscovite, epidote, rutile, and zircon. The chlorite, as is

generally the case, is a secondary mineral resulting from the decomposition of biotite and garnet. Microperthite as well as micropegmatite structures were again observed.

Crystalline limestone.—The colour of all the specimens is a pure white. In texture they are more or less coarse-grained. In two specimens which were taken in the immediate neighbourhood of Naniazeik, the individual crystals measure an inch and a half in diameter. Every single specimen possesses the peculiarity of giving an evil smell, when struck with the hammer. This smell originates from organic matter—probably skatole 

The marble is not a pure crystalline limestone, but more of a dolomitic nature, the relative proportions of calcium and magnesium-carbonates varying indefinitely. The microscope reveals the interesting fact that in numerous instances the individual crystals of the carbonates are distorted and bent.

The marble itself contains numerous minerals whose presence must be ascribed to metamorphic agents. They are enumerated below according to their respective frequency of occurrence and importance. Black metallic graphite in thin hexagonal crystals up to one-tenth of an inch in diameter is abundant in every single specimen of marble.

Forsterite ($Mg_2 Si O_4$), a mineral closely related to *olivine*, from which it is only distinguished in chemical composition by the absence of iron, was repeatedly detected in slides under the microscope. It is colourless in thin sections; never bounded by crystallographic but always by irregular rounded contours, and has a high index of refraction. It polarizes in bright colours, thus showing a high double refraction, and its extinction in all principal sections is straight. In all its optic characteristics it is therefore identical with olivine, and the chemical test alone proves the mineral to be forsterite. Like olivine it is remarkably prone to alteration, and in numerous instances has been converted into serpentine, *i.e.*, antigorite, and as such it presents itself to the whole naked eye, embedded in the marble.

Phlogopite in thin plates of reddish-brown colour is also very abundant. It is distinguished from muscovite by the almost uniaxial interference-figure, which it gives in thin sections between

crossed nicols. *Chondrodite* occurs in numerous crystalline aggregates, varying in size up to half an inch in diameter, and is of a light brown colour. Examined in thin sections under a microscope, it proves slightly pleochroic in light brown colours, shows a high index of refraction and a high double refraction.

Garnet (the red variety known as *hessonite*). It is not as plentiful as might be expected in these metamorphic rocks. Wherever observed, it is never bounded by crystallographic contours but always shows corroded and irregular outlines. *Pyrrhotine* in numerous little grains is generally of secondary origin. *Apatite* must evidently be a rare mineral in this marble, as only one small grain was detected in one slide. Its optic properties are those common to normal apatites.

Tourmaline is of special interest, although its occurrence in the marble is as rare as that of apatite; a dark brown strongly pleochroic mineral, the deep colour appearing when the long axis of the section is perpendicular to the short diagonal of the polarizing nicol, with a high index of refraction and a very high double refraction; these optic properties leave no doubt as to its identity.

Spinel, one tiny little grain of light green colour, is contained in one of the slides. It is not bounded by crystallographic contours and shows signs of corrosion. Rotated between crossed nicols it remains dark.

Other minerals than these were not found in the marble of the Manwe-Naniazeik ruby-tract.

An examination of the gravel taken from the dry bed of the little mountain stream near Manwe, where Kachins formerly washed for corundum, proved of the greatest interest. The constituent minerals of this gravel are *quartz*, *felspar*, *phlogopite*, *chlorite*, *garnet*, *spinel*, and *corundum*. The two latter minerals deserve a short description. They are fairly abundant, more especially so the spinel, a handful of which can be collected in a few minutes. The spinel occurs in octrahedral crystals up to half an inch in diameter. Twin crystals are numerous, the plane of twinning being O (111). Multiple twinning was also recorded. The colours of the spinel vary with the pellucidity from an almost opaque dark green to a bright translucent red. The latter variety of colour however is rare.

The corundum is not nearly as plentiful as spinel. Three pieces of this mineral were found, one of them being nearly three-fourths of an inch in diameter. The colour of this stone is a dull pink. The two smaller pieces show bright and dark red colours respectively.

The *byon* of the ruby-mines at Naniazeik is a light-coloured clay or sand, which consists of the following minerals: *quartz*, *orthoclase*, *phlogopite*, *chlorite*, *calcite*, *plagioclase*, *spinel*, and *ruby*. Neither spinel nor ruby seems to be very abundant. The small chips of rubies however are very beautiful in colour.

To judge by comparison, the occurrence of corundum, *i.e.*, rubies at Naniazeik, is very similar to that of Mogouk and that in the Sagyin hills. In both the latter localities rubies were found embedded in the crystalline limestone, so that there can be no doubt that in either case the ruby in the alluvial soil is derived from the decomposed marble. Now although corundum could not actually be traced by me in the marble at Naniazeik and Manwe it also undoubtedly is contained in the same.

As regards the genesis of the marble and associated minerals in the mountains between Manwe and Naniazeik, it can satisfactorily be explained by the theory of contact-metamorphism. All outward forms of organic remains contained in the limestone previous to its metamorphism must naturally have been completely destroyed by the intense metamorphic action of the intrusive granite. But the presence of skatole as well as that of carbon in the shape of graphite is a strong argument in favour of the explanation that fossil-bearing sedimentary limestones were metamorphosed in contact with granitic intrusions. The contact of marble and granite was discovered *in situ* on the road from Sikaw to Naniazeik. The marble here is literally crammed with contact-minerals, the more conspicuous of which are serpentine, pseudomorphous after forsterite, chondrodite, and phlogopite. The granite itself is very rich in phlogopite. In the immediate contact with marble it assumes a gneissose foliated character. The "gneissose rocks" previously described and found near Manwe undoubtedly originate from a similar zone of contact. At a short distance from the contact the granite gradually re-assumes its ordinary hypidiomorphic structure. The numerous minerals, such as garnet, spinel, chondrodite, etc.,

are typical contact-minerals, produced by intrusive granite in sedimentary magnesian limestone. The action of pneumatolytic agents successively passing outward from the body of the intruded magma is evidenced by the presence of schorl and by the serpentinisation of the newly formed forsterite.

Again, the marble in the Naniazeik ruby-tract was not formed under ordinary conditions of contact-metamorphism. Professor E. Weinschenk has repeatedly pointed out that corundum crystallizes in magnesian limestone under the influence of piezocontact-metamorphism, *i.e.*, of contact-metamorphism acting under abnormal compression due to orographic movements during the consolidation of the rocks. The foliated character of the granite in many places between Manwe and Naniazeik, as well as the distorted and bent crystals of the carbonates as observed under the microscope, are strong arguments in favour of piezocontact-metamorphism. On the other hand such minerals as forsterite, chondrodite, garnet, etc., are generally absent in piezocontact-metamorphic marbles. This is due to the fact that carbonic acid cannot escape during the process of metamorphism under high compression, and that therefore all the lime and magnesia re-crystallize as carbonates. In this case, however, minerals of both types of metamorphism are contained in the marbles. This proves again that compression due to orographic movements could not have exerted a very strong influence on the process of contact-metamorphism, strong enough however to allow corundum to crystallize side by side with minerals composed of the chemical compounds of both limestone and granite. If ordinary contact-metamorphism may be considered as one extreme and piezocontact-metamorphism as another extreme, numerous intermediate stages of contact-metamorphism, generally speaking, must be possible. An intermediate stage therefore would signify that the newly formed minerals must be present in nearly equal quantities. The greater the compression brought to bear on the rocks during the stage of metamorphism and consolidation, the more corundum crystallizes in the marble, whereas garnet, chondrodite, etc., are not formed. On the other hand these latter minerals will be predominant, whenever the conditions of contact-metamorphism become more normal. This theory can therefore satisfactorily explain a scarcity of corundum in the marble at Naniazeik, and also the comparatively speaking rare

occurrence of rubies in the alluvial soil. This comparative scarcity of rubies is a prominent feature in the Naniazeik ruby-tract. As will be readily understood by the above, rubies may occur in larger quantities at different localities in the same tract, and this fact must not be put down to a better concentration of stones by the mechanical action of water by which the alluvial soil was deposited, but also to a greater abundance of the precious stones in the marble. It is therefore by no means precluded that systematic prospecting may be rewarded with the finding of "pockets" rich in stones.

If a similar explanation of genesis may also be applied to the ruby-bearing marble of Mogouk and the Sagyin hills, it would signify that the metamorphism in these parts is more typical of piezocontact-metamorphism The absence of forsterite and chondrodite as well as the gneissose character of the granite tend to corroborate this view. Messrs. Brown and Judd, however, maintain that the ruby-bearing marble in the Burma Ruby Mines district is of purely chemical inorganic origin. Although it is difficult to conceive that two or more similar occurrences in one and the same country should be of absolutely different origin, it must again be emphasized that the rubies at Naniazeik were produced by contact-metamorphism and that an explanation such as that given by Messrs. Brown and Judd for the genesis of the ruby-bearing marble at Mogouk is absolutely impracticable for the crystalline limestone at Naniazeik.

THE CRETACEOUS ORBITOIDES OF INDIA. BY ERNEST W. VREDENBURG, A.R.S.M., A.R.C.S., F.G.S., *Geological Survey of India.* (With Plates 25 to 29.)

CONTENTS.

INTRODUCTION.

SEVERAL species of *Orbitoides* (*sensu lato*) have been met with in the Upper Cretaceous deposits of Balúchistán and Sind in north-western India, in Tibet, and on the Coromandel coast of southern India. These are—

Orbitoides media d'Arch. . .	Mari hills and Suleimán range of Balúchistán and Punjab; Tibet.
" *Hollandi* n. sp. . .	Mazar Drik in the Mari hills.
" *apiculata* Schlumb. .	Barra hill in Sind.
" *minor* Schlumb.? .	Suleimán range, Niniyur beds of the Trichinopoli district in the Coromandel.
" *socialis* Leym. . .	Mari hills.
" sp. indet. . .	Post-Ariyalur beds of the Pondicherri district in the Coromandel.
Omphalocyclus macropora Lam. .	Mari hills and Kalát region in Balúchistán; Tibet.

Before proceeding with the description of these fossils, it will be useful to give some details regarding the stratigraphy of the rocks in which they have been found.

PART I.—STRATIGRAPHICAL.

CHAPTER I.—GEOLOGICAL OCCURRENCE OF THE ORBITOIDES.

1. Orbitoides-Bearing Beds of the Mari Hills.

a.—DES VALLEY SECTION.

From the above list it can be seen that it is the Mari hills of Balúchistán that have yielded the greatest number of species. Fossils

were collected from these beds by R. D. Oldham, Hira Lal, and Kishen Singh in 1890-1891, by R. A. Townsend in 1891-1892, by C. L. Griesbach and Kishen Singh from 1892 to 1894. Detailed descriptions of these organic remains were published in the Palæontologia Indica (Ser. XVI, Vol. I, part 3, 1897), by Dr. Noetling, who came to the conclusion that the bulk of the fauna indicates a Maestrichtian age (the term Maestrichtian being understood as defined by de Lapparent in the 3rd, 4th, and 5th edition of the "Traité de Géologie"). These collections were obtained mainly from two localities, the Des Valley and Mazar Drik, both situated in the Mari hills. The Des Valley is near the oil well of Khatan whose exploration led to the discovery of this interesting fauna. The fossils from this locality collected by R. D. Oldham, Hira Lal, and Kishen Singh, were obtained principally from three horizons, numbered respectively 2, 4, and 8, in the sections studied by Oldham. In the Mazar Drik section examined by C. L. Griesbach and Kishen Singh, the fossils were collected without reference to special horizons.

In order to fix the zonal distribution of the various species more accurately, the sections were re-examined in 1898 by Dr. Noetling, who obtained a good collection of fossils including nearly all those that had been obtained previously, as well as a number of other species not previously discovered. Those from Mazar Drik were obtained from three principal horizons numbered respectively 6, 13, and 14. Those from Des were obtained from a series of strata about 500 feet thick including zones 2 to 24 of the section examined by Dr. Noetling. The locality is in the neighbourhood of Thur Kund (Lat. 29° 35′; Long. 68° 30′). A drawing to scale representing the succession of these beds has been published by Dr. Noetling in the "Centralblatt für Mineralogie, Geologie and Palaeontologie" for 1903, p. 515, together with preliminary lists of fossils. These lists were drawn up from rough identifications in the field. I have examined the collections at greater leisure, and identified the species enumerated below, which do not include the totality of the fossils as a number of them still await identification and description.

According to Dr. Noetling's observations, the lowest fossiliferous beds, constituting zone No. 2, consist of calcareous nodular shales about 10 feet thick. The following fossils have been identified in Dr. Noetling's collection from this zone: *Sphenodiscus acutodorsatus*

Noetl. (abundant), *Gaudryceras* sp. (cf. *G. Kayei* Forbes), *Heteroceras* sp.

Zone 4, separated from zone 2 by about 50 feet of unfossiliferous soft shales, consists of about 35 feet of nodular limestones with shaly partings, containing: *Orbitoides media* d'Arch., *Clypeolampas Helios* Noetl., *Hemipneustes compressus* Noetl.,[1] *Hemiaster Oldham* Noetl., *Alectryonia pectinata* Lam., *A. larva* Lam. (rare) *Spondylus subserratus* Douvillé, *S. calcaratus* Forbes, *Neithea quinqueangularis* Noetl., *N. quadricostata* Sow., *N. striatocostata* Goldf., *Pecten Dujardini* Roem., *Turritella sexlineata* Roem., *Pachydiscus dülmensis* Schlüt., *Heteroceras polyplocum* Roem., *Peroniceras* sp.

This zone is succeeded by two zones 5 and 6, lithologically similar to it, whose aggregate thickness amounts to 30 feet. Zone 5 contains *Clypeolampas Helios* Noetl., *Hemipneustes compressus* Noetl., *Neithea quadricostata* Sow. The only fossil collected in zone 6 is a large smooth *Pecten* which also occurs in zone 5.

Zones 7 and 8 are also lithologically similar to those just mentioned. The fossils of Dr. Noetling's collection from zone 7 include: *Orbitoides media* d'Arch., *Cidaris Suleimani* Noetl. (closely related to *Cidaris persica* Cott. et Gauth.), *Holectypus baluchistanensis* Noetl., *Clypeolampas Helios* Noetl., *Hemipneustes compressus* Noetl., *Hemiaster tamulicus* Kossmat (identical with *Hemiaster Blanfordi* Noetl.[2]), *Spondylus calcaratus* Forbes, *Neithea quadricostata* Sow. This horizon corrresponds with zone 2 of Oldham's collection.

The only fossils collected in zone 8 are *Clypeolampas Helios* Noetl., and *Hemipneustes compressus* Noetl.

Zones 9 to 12 are also lithologically similar to the underlying ones,

[1] The fossils referred by Dr. Noetling to *Hemipneustes pyrenaicus* Hebert, and *H. Leymeriei* Heb., cannot be distinguished from *H. compressus* Noetl. The shape is the only character that has been used by Noetling as a distinguishing feature. But the numerous specimens now available show that the shape is extremely variable, and exhibit every imaginable gradation between the three forms originally distinguished by Noetling. The variations in shape are not connected with the vertical distribution, specimens of all shapes occurring in every zone. The species is probably identical with *Hemipneustes persicus* Cotteau et Gauthier.

[2] The date of publication of Vol. XXX, part 2, of the *Rec. Geol. Surv. of Ind.*, containing Kossmat's description is 25th June, 1897. The name *Hemiaster Blanfordi* Noetling, first appears in *Rec. Geol. Surv. of Ind.*, Vol. XXVI, p. 126, in 1894. But as the description and figures did not appear till 31st August 1897, priority belongs to Kossmat's name.

and amount to 100 feet in thickness according to Dr. Noetling. Zone 9 contains *Hemipneustes compressus* Noetl. No fossils appear to have been obtained from zone 10. Zone 11 contains: *Orbitoides socialis* Leym., *Omphalocyclus macropora* Lam., *Cyphosoma speciale* Cott. et Gauth, *Noetlingia* sp. (it has more numerous tubercles than *N. paucituberculata* found at a higher horizon), *Holectypus baluchistanensis* Noetl., *Pyrina orientalis* Cott. et Gauth (Noetling's *P. ataxensis* Cotteau), *Echinanthus Griesbachi* Noetl., *Clypeolampas Vishnu* Noetl., *Alectryonia larva* Lam (plentiful), *Pycnodonta vesicularis* Lam., *Neithea quinqueangularis* Noetl., *N. quadricostata* Sow., *Pecten Dujardini* Roem., *Pholadomya tigris* Noetl., *Turritella sexlineata* Roem., *Cerithium Ganesha* Noetl., *Gisortia* sp.,[1] *Sphenodiscus acutodorsatus* Noetl., (rare) *Sph.* sp. (cf. *Sph. Shiva* Forbes, very abundant), *Pachydiscus dülmensis* Schlüt. There are no fossils from zone 12.

These beds are succeeded by 65 feet of unfossiliferous dark-blue thin-bedded shaly clay, Dr. Noetling's zone 13. It is overlaid by zones 14 and 15, amounting together to 40 feet, consisting of dark-blue nodular limestones with argillaceous partings. Amongst the fossils from zone 14, the following have been identified: *Omphalocyclus macropora* Lam., *Cyphosoma speciale* Cott. et Gauth., *Pyrina orientalis* Cott. et Gauth., *Hemiaster tamulicus* Kossmat, *Turritella Forgemolli* Coquand (Noetling's *Nerinea Quettensis*), *Turritella quadricincta* Goldf., *Cerithium Ganesha* Noetl., *Cer. Buddha* Noetl.

Zone 15 contains *Omphalocyclus macropora* Lam., *Noetlingia paucituberculata* Noetl., *Holectypus baluchistanensis* Noetl., *Pyrina orientalis* Cott. et Gauth., *Echinanthus Griesbachi* Noetl., *Hemipneustes compressus* Noetl., *Neithea quadricostata* Sow., *Cerithium Ganesha* Noetl., *Pugnellus digitatus* Noetl., *Gisortia baluchistanensis* Noetl.

Zone 16, lithologically related to the preceding ones, and about 15 feet thick, contains *Omphalocyclus macropora* Lam. (large and plentiful), *Pyrina orientalis* Cott. et Gauth., *Echinanthus Griesbachi*

[1] The numerous fossils from the Mari hills described by Noetling under the generic name *Ovula* are almost entirely in the condition of casts. Yet, a careful examination of the numerous specimens demonstrates conclusively the presence of the smooth columella, the anterior crenulations and posterior apophysis of the outer lip, characterising the genus *Gisortia*. There is no doubt therefore that the first occurrence of this genus takes place in cretaceous times.

Noetl., *Hemipneustes compressus* Noetl., *Pugnellus crassicostatus* Noetl.

Zones 17 and 18 are soft dark-blue rather shaly limestones with clay partings, of an aggregate thickness of about 35 feet. There are no fossils in Noetling's collection from zone 17. Zone 18 contains *Omphalocyclus macropora* Lam., and *Nerita d'Archiaci* Noetl.

Zone 19, a very hard dark-grey limestone with clay partings, about 25 feet thick, contains *Omphalocyclus macropora* Lam. and casts of *Radiolites Muschketoffi* Noetl.

Zone 20 is a group of olive-coloured shales with a few calcareous partings in which fossils occur inside calcareous nodules, very similar to the well-known nodules of the Spiti Shales. The following forms have been identified: *Orthopsis perlata* Noetl., *Holectypus baluchistanensis* Noetl., *Cardita subcomplanata* d'Arch., *Cardium loralaiense* Noetl., *Cyprina desensis* Noetl., *Pugnellus crassicostatus* Noetl., *P. giganteus* Noetl., *Gisortia expansa* d'Arch. et Haime,[1] *Volutilithes dubia* Noetl., *Physa Prinsepii* Sow., *Sphenodiscus Ubaghsi* de Grossouvre.

Zones 21 to 23 are not represented by any fossils in the collection. According to Dr. Noetling's descriptions, zone 21 is a red sandstone 8 feet thick, zone 22 a red shale 5 feet thick, and zone 23 a dark-brown clay, with layers and partings of brown limestone, the total thickness of which is 15 feet, and which occasionally contains fragments of *Indoceras baluchistanense* Noetl. These fragments cannot be traced in the collection, and Dr. Noetling states that the "best preserved specimen comes from the previous horizon," that is, the fossiliferous zone 20 (General Report for 1898-1899, page 56). The specimen referred to is therefore the one of *Sphenodiscus Ubaghsi*, which is similar in outward appearance to *Indoceras baluchistanense*, the difference becoming apparent only on developing the sutures. This confusion is of no consequence, for the collection from Mazar Drik shows that *Indoceras baluchistanense* does occur at this same horizon.

[1] According to d'Archiac and Haime, the type specimen from Sind comes from a limestone containing nummulites. The species does not occur amongst the Survey collections from the nummulitic of Sind, but both Fedden and Noetling have identified one of the Cretaceous forms as probably representing d' Archiac and Haime's type.

Zone 24, according to Dr. Noetling, consists of a band about 20 feet thick of hard brown calcareous sandstone. It contains *Cardita Beaumonti* d'Arch.

This is succeeded by 100 feet of black unfossiliferous shales overlaid by limestone of Lutetian age.

In Oldham's collection, zone 4 corresponds principally with Noetling's zones 11 to 16, and zone 8 with Noetling's zone 20 to 24.

b.—MAZAR DRIK SECTION.

Mazar Drik is situated in Lat. 29° 50′ and Long. 68° 41′, towards the northern border of the Mari hill country, in the valley of the Beji river. The stratigraphical details of the section have not been published. The upper cretaceous fossils collected by Dr. Noetling were obtained from seven zones, numbered 3, 4, 5, 6, 9, 13, and 14. The only recognisable fossil from zones 3 and 4 is *Neithea quadricostata* Sow. The only fossil from zone 5 is a cast of a *Pugnellus*, perhaps *P. crassicostatus* Noetl. Zone 6 contains *Orbitoides media* d'Arch., *Cidaris Suleimani* Noetl., *Noetlingia* sp. (the same as in zone 11 of the Des valley), *Holectypus baluchistanensis* Noetl., *Pyrina orientalis* Cott. et Gauth., *Clypeolampas Vishnu* Noetl., *Hemipneustes compressus* Noetl., *Hemiaster tamulicus* Kossm., *Alectryonia pectinata* Lam., *Al. larva* Lam., *Pycnodonta vesicularis* Lam., *Neithea quinqueangularis* Noetl., *N. quadricostata* Sow., *Cerithium Ganesha* Noetl., *Volutilithes dubia* Noetl. This zone corresponds principally with zone 11 of the Des valley, probably including also a few forms from a slightly lower horizon.

The only fossil from zone 9 is an undescribed *Orbitoides* which I have named *O. Hollandi.*

Zone 13 of Mazar Drik contains the same fauna as zone 20 of the Des valley. The following forms have been identified: *Trochosmilia protectans* Noetl., *Hemipneustes compressus* Noetl. (rare), *Plicatula hirsuta* Coqu. (Noetling's *Hinnites* (?) *foliaceus*), *Cardita subcomplanata* d'Arch., *Cardium loralaiense* Noetl., *Chama callosa* Noetl., *Turritella sexlineata* Roem., *T. quinquecostata* Noetl., T. *quadricincta* Goldf., *Cerithium Ganesha* Noetl., *Pugnellus crassicostatus* Noetl., *P. digitatus* Noetl.,

Gisortia expansa d'Arch. et Haime,[1] *Physa Prinsepii* Sow.,[2] *Indoceras baluchistanense* Noetl., *Pachydiscus* sp. (probably *P. neubergicus* F. von Hauer).

Zone 14 of Mazar Drik is the horizon of *Cardita Beaumonti*, corresponding with zone 24 of the Des valley. In addition to the above named fossil, the species *Cardium loralaiense* Noetl., and *Gisortia expansa* d'Arch. and Haime have been identified.

The original collection from Mazar Drik which constitutes part of the material described in Dr. Noetling's monograph, was not gathered with reference to zonal distribution, and, unfortunately, the majority of those forms described in the monograph which have not reappeared in the latter collection (9 out of 13), were from Mazar Drik. The most interesting of those forms whose exact horizon for the present cannot be determined, are: *Modiola Vishnu* Noetl., *Cardium harnaiense* Noetl., *Cyprina mazariana* Noetl., *Roudairia crassoplicata* Noetl., *Voluta-latisepta* Stol.

The above lists of Dr. Noetling's collections represent only a portion of the species which they include. I have mentioned only those forms whose identification appears sufficiently secure.

2. Jhalawán (Kalát State).

During the winter of 1905 to 1906, I recognised the same beds over a considerable part of Balúchistán, principally in the Jhalawán province of the State of Kalát, but could not dispose of sufficient leisure to sub-divide the beds as minutely as has been done by Dr. Noetling in the Des valley. I have always been able, however, to separate three principal horizons: a lower one, the *Hemipneustes* beds corresponding principally with zones 7 to 18 of the Des valley, a middle horizon with *Cardita subcomplanata* corresponding with zones 20 to 23 of Des, and an upper horizon, the *Cardita Beaumonti* beds, whose base corresponds with zone 24. This tripartite division

[1] See the note regarding the occurrence of this species in the Des valley (*supra*, page 176).

[2] When first describing the occurrence of this species amongst the Des valley fossils, I mentioned that the specimens did not reach the size usually attained by those from the Intertrappeans of the Peninsula (*Rec. G. S. I.*, XXXV, p. 116). I had not then examined the collections from the same horizon at Mazar Drik, where the specimens are much larger, and equal in size to the average of the Peninsular ones.

is essentially that adopted by Dr. Noetling for the Mazar Drik collection.

In Jhalawán, a sub-divisional distinction which does not seem to hold good in the Des and Mazar Drik sections, is furnished by the two very abundant oyster species, *Pycnodonta vesicularis* Lam., and *Alectryonia larva* Lam. In the Des valley they both occur together in great abundance in zone 11. But in Jhalawán, *Alectryonia larva* is especially abundant at a horizon situated higher than the zone characterised by *Pycnodonta vesicularis* and by a great abundance of *Hemipneustes.* It is this lower zone that appears to correspond with zone 11 of Des, while the higher beds specially characterised by *Alectryonia larva,* and containing a great abundance of large specimens of *Omphalocyclus macropora,* appear to correspond with zones 15 to 16 of the Des valley.

The following details of a few of the sections examined will show their general similarity with those examined by Dr. Noetling.

In the region of the Mula pass near Kharzán (Latitude 28° 2', Longitude 67° 10'), the successive beds are shown in a very clear section where they all dip east by south, at an angle of about 45°. The *Hemipneustes* beds proper, that is the lower sub-division above alluded to, are grey limestones in hard beds alternating with softer shaly limestones, with a total thickness of some 100 feet. They contain *Omphalocyclus macropora* Lam. (large specimens), *Hemipneustes compressus* Noetl., *Hemiaster tamulicus* Kossm., *Pycnodonta vesicularis* Lam. (abundant), *Alectryonia larva* Lam. (rare), *Neithea striatocostata* Goldf., *Neritina d'Archiaci* Noetl., *Desmieria pontica* d'Arch., *Hantkenia striata* Douvillé.

This sub-division is succeeded by about 200 feet of unfossiliferous shales with intercalations of limestone in their uppermost layers. These are overlaid by about 60 feet of shales and dark limestones with numerous specimens of *Alectryonia larva.*

A band of unfossiliferous soft sandstone, sometimes only 15 feet thick, but locally expanding considerably when followed along the strike, separates these beds from the overlying sandstones associated with dark brown or black limestones, with a total thickness of about 40 feet, containing *Cardita Beaumonti.* The latter are followed by a considerable thickness first of sandstones and thën of arenaceous shales, amounting together to about 300 feet, capped by thick flows

of basalt (the Deccan Trap), immediately succeeded by nummulitic limestones of Lutetian age.

In the above section, the unfossiliferous soft sandstones of varying thickness occurring between the *Alectryonia larva* and *Cardita Beaumonti* beds probably represent the beds with *Cardita subcomplanata*, *Sphenodiscus Ubaghsi*, *Indoceras baluchistanense*, etc., constituting zones 20 to 23 of the Des valley, and zone 13 of Mazar Drik. The sandstones and arenaceous shales intercalated between the strata with *Cardita Beaumonti* and the basalt, represent a portion of the "Pab sandstones" (*Rec. G. S. I.*, XXXV, p. 117), which assume so much importance in the Pab range of southern Jhalawán and Las Béla.

Along the continuation of the same outcrop about 15 miles further to the south-east, at a locality called Wad (not to be confounded with another place of the same name situated some 60 miles to the south-west, in southern Jhalawán), the same beds are again clearly exposed with an easterly dip of 25°. The only abundant fossil in the *Hemipneustes* and *Alectryonia* sub-divisions is *Omphalocyclus macropora* which occurs at all horizons. The lowest fossiliferous bed, which rests on a considerable thickness (about 120 feet) of unfossiliferous soft, greenish, calcareous shales, consists of a massive dark grey limestone, about 20 feet thick, followed by about the same thickness of massive hard white sandstone; then by about 50 feet of massive dark grey limestone, and by another 50 feet of thinner bedded hard grey limestone alternating with softer shaly bands, the uppermost layers containing numerous specimens of *Alectryonia larva*. These beds are overlaid by greyish green sandstones succeeded by arenaceous shales of flysch appearance, both unfossiliferous, and amounting to about 90 feet. Next come 30 feet of dark sandstone full of fragmentary basaltic material, succeeded by another 70 feet of olive-coloured sandstones and arenaceous shales. Next come about 20 feet of dark brown limestone with *Cardita Beaumonti*, another 20 feet of dark green sandstones, and finally about the same thickness of basaltic tuffs (Deccan Trap), crowded with shell fragments. These are overlaid by the nummulitic limestone of Lutetian age.

Near Karu, about 11 miles south of the section last described, an elongated dome-shaped anticline again gives a clear view of these

various strata. The *Hemipneustes* beds consist of pale grey limestones, the uppermost beds of which contain *Alectryonia larva* in great abundance; they are rather massive and are abruptly overlaid by dark olive green soft crumbling shales, the colour being probably due to the presence of volcanic dust. The change of facies probably corresponds with the commencement of the great Deccan Trap eruptions. The olive shales are interbedded at intervals with thin bands of a peculiar dark rock of porcellanoid appearance, but very brittle; it is often full of calcareous concretions, similar to those of zone 20 of the Des valley. At one horizon only do these contain fossils. About 100 feet of these olive shales intervene between the top of the *Hemipneustes* limestones and a massive coarse sandstone about 40 feet thick succeeded by another 200 or 300 feet of olive shales in every respect similar to those beneath the sandstone. The fossiliferous horizon is situated some 10 to 15 feet below the base of the massive sandstone, and consists of two bands of the peculiar porcellanoid rock separated from one another by about 2 feet of shale. The lower band is by far the richest. It is remarkably constant for distances of several miles along the Karu anticline, but is rarely accessible, and only six inches thick. With the exception of this horizon, the olive shales are quite unfossiliferous. At their upper limit, the olive shales are succeeded by some gritty calcareous bands containing a few fossils, representing some of the *Cardita Beaumonti* layers of the sections previously described. These are overlaid by a great thickness of massive brown limestones with fossils that do not weather out, and lastly by the tuffs of the Deccan Trap, here of great thickness and crowded with fossils, none of which weather out, with the exception of a very large species of *Nautilus*.

Amongst the fossils obtained from the *Hemipneustes* beds of the Karu anticline, the following have been identified: *Omphalocyclus macropora* Lam., *Hemipneustes compressus* Noetl., *Hemiaster tamulicus* Kossm., *Pycnodonta vesicularis* Lam., *Alectryonia larva* Lam. (only in the uppermost beds), *Neithea striatocostata* Goldf., *Desmieria pontica* d'Arch., *Peroniceras* sp. (the same species as in zone 4 of the Des valley), *Pachydiscus dülmensis* Schlüt., *Baculites* sp.

Those identified amongst the fauna of the fossiliferous horizon in the olive shales include: *Cardita subcomplanata* d'Arch., *Pugnellus*

crassicostatus Noetl., *Sphenodiscus Ubaghsi* de Grossouvre, *Schlüteria Larteti* Seunes, *Pachydiscus neubergicus* von Hauer, *Baculites* sp. There are many other fossils none of which correspond with any of the Des or Mazar Drik species, but the first three species above mentioned are sufficiently characteristic to establish the identity of this zone with that of *Sphenodiscus Ubaghsi* and *Indoceras baluchistanense* in the area studied by Dr. Noetling.

The above-described sections in the Jhalawán region are quite in harmony with those studied by Dr. Noetling in the country of the Mari hills.

Attention may be drawn to the fact that *Neithea striatocostata* and *N. quadricostata* appear to replace one another in the *Hemipneustes* beds of the Mari hills, and Jhalawán regions. *N. striatocostata* is very rare in the Mari hills, where it is represented only by a few specimens in zone 4 of Des, while *N. quadricostata* is extremely abundant throughout the *Hemipneustes* beds of Des and Mazar Drik. In Jhalawán both species also occur, but the proportions are reversed: *N. quadricostata* is only represented by a few fragments in the lower part of the *Hemipneustes* beds of Kharzán, while both at Kharzán and Karu, *N. striatocostata* occurs abundantly throughout the horizons which at Des and Mazar Drik contain a great abundance of *Neithea quadricostata*. Further west, in the Maestrichtian beds studied by de Morgan in western Persia, *N. quadricostata* appears to be missing, while *N. striatocostata* is very abundant. (H. Douvillé *in* Mission Scientifique en Perse par J. de Morgan; Mollusques fossiles, p. 267, Pl. XXXIX, figs. 5-8, 1904.) The area intervening between Jhalawán and the Mari hills seems to have represented locally a mutual limit of distribution of the two species. Far to the east, in Tibet, the specimens collected by Mr. Hayden all belong to *N. quadricostata*. (*Mem. G. S. I.*, XXXVI, p. 166.)

In all the above-described sections, both in the Mari hills and Jhalawán regions, the base of the *Hemipneustes* beds rests either directly or with the intervention of a variable thickness of unfossiliferous shales, upon compact porcellanic limestones of lower Cretaceous age. The Gault, Cenomanian, Turonian, and Lower Senonian are invariably missing in Balúchistán.

3. Western Persia.

In western Persia, de Morgan has distinguished two principal horizons in the Upper Senonian beds, a lower one distinguished as the Echinoid beds, and an upper one constituting the Cerithium beds. The latter is divided into two zones, the fossils from which could not be kept separate. It was ascertained, however, that *Omphalocyclus macropora* characterises the lower zone, and *Iraniaster Morgani* the upper one. (Douvillé, *loc. cit. supra*, p. 282-283.)

In the Echinoid beds of western Persia, the following species are identical with or closely allied to fossils from Balúchistán: *Cyphosoma speciale* Cott. et Gauth., *Pyrina orientalis* Cott. et Gauth., *Hemipneustes persicus* Cott. et Gauth., *Pycnodonta vesicularis* Lam., *Plicatula hirsuta* Coqu., *Spondylus subserratus* Douvillé, *Neithea striatocostata* Goldf., *Heteroceras polyplocum* Roem., *Sphenodiscus acutodorsatus* Noetl. With the exception of *Plicatula hirsuta* occurring in the zone of *Indoceras baluchistanense* at Mazar Drik, all the other species in Balúchistán are characteristic of the *Hemipneustes* beds. In the Des section they all belong to zone 11 or to lower horizons, with the exception of *Pyrina orientalis*, which is particularly abundant in zone 15.

In the Cerithium beds of western Persia, the forms identical with or closely related to those met with in Balúchistán, are: *Omphalocyclus macropora* Lam., *Chama* cf. *callosa* Noetl., *Cardita* cf. *subcomplanata* d'Arch., *C. Beaumonti* d'Arch., *Turritella quadricincta* Goldf., *Hantkenia striata* Douvillé.

In Balúchistán, *Omphalocyclus macropora* has not been found in the zone that contains *Cardita subcomplanata*, *Sphenodiscus Ubaghsi*, and *Indoceras baluchistanense*, but this may be a mere question of facies since these beds do not contain any foraminifera. *Hantkenia striata* has been met with in the *Hemipneustes* beds of Kharzán. The remaining four species, or closely allied ones, occur, in Balúchistán, in the uppermost ammonite zone with *Cardita subcomplanata*, or in the overlying beds with *Cardita Beaumonti*.

Two more species of the Cerithium beds of Persia, *Cerithium Stoddardi* Hisl., and *Morgania*[1] *fusiformis* Hisl., occur, in India, in the Rajamahendri intertrappeans, as is also the case with *Physa*

[1] This name has been substituted by Cossmann for Douvillé's generic name *Irania* preoccupied in the zoological nomenclature for a genus of birds. (*Rev. crit. paléoz.*, X, 1906, p. 196.)

Prinsepii occurring in the *Cardita subcomplanata* beds of Des and Mazar Drik.

It is clear that the Echinoid beds of western Persia correspond with the *Hemipneustes* beds of Balúchistán, while of the *Cerithium* beds, the lower zone answers to the zone of *Cardita subcomplanata, Sphenodiscus Ubaghsi,* etc., in Balúchistán, and the upper zone to overlying beds with *Cardita Beaumonti.*

At the Pusht-i-Koh, de Morgan noticed that the Echinoid beds rest directly on Lower Cretaceous strata, indicating a hiatus similar to that observed in Balúchistán.

4. The Suleimán Range.

In 1906, I obtained specimens of *Orbitoides media* and O. cf. *minor* in the Suleimán range near Fort Munro. The section has not been made out with as much detail as in the Mari hills and in Jhalawán, but its general similarity is nevertheless evident.

The Suleimán range in the Fort Munro region is a great anticlinal arch consisting principally of the Pab sandstones which here, as in the Pab range, attain a thickness of 2,000 feet or more. Nummulitic beds are observed along the outer (eastern) limb of the anticlinal arch, where they form ridges of minor elevation as compared with the Pab sandstones of the main axis. In Volume XX of the Memoirs of the Geological Survey of India, p. 218, Dr. Blanford has published a section across the range quite similar to that observed at Fort Munro. The section figured by Blanford is situated about 25 miles south of that locality.

The beds underlying the massive sandstone are only seen where the anticlinal arch has been cut through by deep river gorges, such as that of the Rakhi along which passes the road from Dera Ghazi Khan to Fort Munro. The lowest beds exposed in the Rakhi gorge are the *Hemipneustes* beds, consisting of about 700 feet of grey limestones with calcareous shaly partings. I gathered the following fossils from these beds: *Orbitoides media* d'Arch., *Holectypus baluchistanensis* Noetl., *Echinanthus Griesbachi* Noetl., *Hemipneustes compressus* Noetl. The massive sandstones overlying these beds are several thousand feet thick (2,000 at least). They are white, but weather of a black colour. They are overlaid by black sandstones full of volcanic material, and crowded with fragmentary fossils. These are overlaid by a black

limestone whose base is lateritic, and which passes upwards into nummulitic beds of lower Lutetian age.

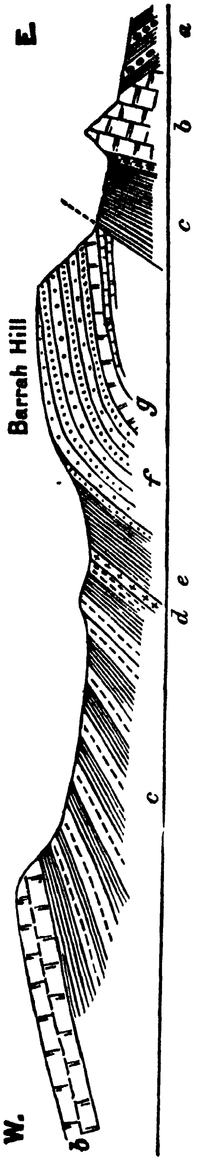


FIG. 1.—Section at Barrah Hill.
a.—Manchhar (Siwalik). *b.*—Alveolina limestone (Laki). *c.*—Lower Ranikot.
a.—Deccan Trap. *e.*—Olive shales with *Cardita Beaumonti.* *f.*—Pab sandstones. *g.*—Limestone with *Orbitoides.*

I was unable to search for fossils in the sandstones. But in a talus formation at Rakhi Munh derived from slopes outside the reach of the denudation products of the *Hemipneustes* beds, and therefore containing fragments of rocks only newer than that stage, some of the sandstone blocks are crowded with small *Orbitoides* whose characters, so far as can be made out, agree with those of *O. minor* Sclumb. They are probably derived from the lower portion of the Pab sandstones.

5. Laki Range in Sind.

In Sind, Cretaceous *Orbitoides* have been obtained only at one point in the Laki range, that known as Barrah hill, a section of which has been figured by Dr. Blanford (Geology of Western Sind, Pl. V, fig. 2).

The section at Barrah hill exhibits the lowest beds exposed in western Sind, along the axis of an anticline in which overfolding is combined with a certain amount of overthrust. Blanford's section is here reproduced with the only difference that the feature shown by him as an ordinary fault with downthrow to the east, is represented with greater probability as an overthrust.

The lowest bed shown in Blanford's section consists of a massive white and grey limestone, very hard and compact, full of fossils which do not weather out. Blanford did not detect

any foraminifera, but obtained one fragment regarded as that of a hippurite, in consequence of which this limestone was regarded as possibly the equivalent of the Turonian hippuritic limestone of eastern Persia. This specimen cannot now be traced, but when I visited the section in 1906, I noticed that at the base of the massive limestone, there are thinner bedded layers of a very hard buff-coloured limestone abounding in specimens of an *Orbitoides* which I have identified as *O. apiculata*. These lowermost beds were not detected by Blanford, and were perhaps concealed by talus at the time of his visit. The presence of this *Orbitoides* shows that the beds cannot be older than Maestrichtian, and the section is thus brought into harmony with those of Balúchistán.

The upper beds of the massive limestone are gritty, and pass upwards into sandstones, conglomerates, dark gritty limestones, and ferruginous bands, all weathering of a very dark colour. They correspond with the Pab sandstones. Their total thickness is about 800 feet. They pass upwards into about 500 feet of olive shales with calcareous partings containing *Cardita Beaumonti*, capped by a basalt flow of the Deccan Trap, succeeded by eocene sandstones and clays. Instead of being of middle eocene age as in the Balúchistán sections hitherto described, they belong to the lower eocene Ranikot series.

6. Tibet.

In Tibet, my colleague Mr. Hayden has observed a fine development of the Upper Cretaceous in a more or less faulted synclinal belt extending for a distance of about 50 miles from the neighbourhood of Kampa-Dzong to that of Tüna, in a north by west to east by south direction, parallel therefore to the strike of the Himalaya, and situated about ten miles north of the northern spurs of the great snowy range of Sikkim. The sequence, full details of which are given in Mr. Hayden's recently published Memoir on Central Tibet (*Mem. G S. I.*, Vol. XXXVI, pt. 2, 1907), is more complete than that of Balúchistán, and resembles that observed in certain parts of Persia and of southern India, owing to the Cenomanian being represented as well as the Senonian. Above "a series of brown shaly limestones with brown and black needle shales" containing cenomanian ammonites, is "a band of pale grey shale about 250 feet thick," whose lowermost beds are fossiliferous and contain well-preserved specimens of *Hemiaster* regarded by Mr Hayden as also cenomanian.

Above these shales there are three compact limestone bands, each of which is about 150 feet thick, separated by approximately equal thicknesses of softer beds, so that they form a succession of conspicuous scarps, the dip being usually towards the north. The uppermost (third) limestone is succeeded by another 140 feet or so of thin-bedded limestones with arenaceous intercalations, and lastly by a ferruginous sandstone overlaid by eocene strata. The strata intervening between the third limestone and the ferruginous sandstone have been distinguished as the "Tüna limestones," and are those richest in determinable fossils distributed through several remarkably constant zones.

The first compact limestone and the shales intervening between it and the second limestone have not yielded any determinable fossils. From the base of the second limestone to the top of the third limestone, *Orbitoides media* is found in great abundance, the finest specimens occurring within the third limestone; it is accompanied by numerous though fragmentary remains of "Rudistæ" which have not been identified. *Pycnodonta vesicularis* occurs in the higher beds of the third limestone, whose uppermost strata are characterised by a species of *Actæonella*. *Orbitoides media* also extends into the thin "bedded limestones forming the lowermost portion of the overlying Tüna limestones," but in the succeeding brown limestones it is replaced by *Omphalocyclus macropora*. The latter foraminifer is accompanied by *Neithea quadricostata*, by an undeterminable species of *Holectypus*, and a *Hemipneustes* closely allied to *H. depressus* Noetl. and *H. persicus* Cott. et Gauth.; it is proportionately narrower, and much more regularly oval than either of these species, with the apex more central, further removed from the posterior margin; both the anterior and posterior extremities of the test are more attenuated and less truncated than in the species from Balúchistán and Persia; the oval outline of the ambitus closely resembles that of *H. striato-radiatus* from Maestricht, but the test is vertically more depressed; the Tibetan echinoid agrees with *H. depressus* and *H. persicus* and differs from the Maestricht species in the great breadth of the posterior poriferous zones of the paired ambulacra: it might be called *Hemipneustes tibeticus*.

Overlying the brown limestone, are a grey limestone, a red

arenaceous limestone, and a coral limestone, almost entirely made up of *Lithothamnia*, the aggregate thickness of these three divisions amounting only to 20 feet, the *Lithothamnion* limestone, in particular, including but a few inches. These are the zones that have yielded the largest number of determinable fossils. The collection from the red arenaceous limestone includes *Pyrina* cf. *gigantea* Noetl., *Hemipneustes tibeticus, Plicatula hirsuta* Coquand, *Neithea quadricostata*, and fragments of a large *Campanile* related to *Cerithium Ganesha* Noetl. The collection from the *Lithothamnion* limestone includes a species of very small *Orbitoides* related perhaps to *O. minor*, *Omphalocyclus macropora*, *Cyclolites regularis*, *Echinobrissus* sp., *Vologesia?* sp. nov., *Echinanthus* sp. (a species closely related to an undescribed form occurring in the *Indoceras* zone of Mazar Drik), *Hemipneustes tibeticus*, and a curious fossil resembling a *Caprina*. The echinoid above referred to as perhaps a *Vologesia*, differs from the Persian form *V. Tataosi*, (Cotteau et Gauthier, Mission de Morgan, Echinides, p. 66, 1895) the only described species of the genus, by its ambulacral petals which are more completely closed. The actinal surface is not quite so flat as in the Persian generic type, yet its convexity is very slight, and its junction with the hemispherical dorsal surface as abruptly angular as in *V. Tataosi*. The apical disk is concealed, but the peristome and periproct agree in shape and position with the type. The generic diagnosis of *Vologesia* might perhaps be extended so as to include forms with closed petals, or else the latter might constitute a sub-generic division under the name of *Haydeniaster*.

The Lithothamnion limestone is succeeded by 30 feet of sandstone and 50 feet of limestone, neither of which have yielded any recognis able fossils. These are overlaid by 200 feet of ferruginous sandstone upon which rest limestones of eocene age.

The above lists show that in addition to the foraminifera *Orbitoides media* and *Omphalocyclus macropora*, the uppermost Cretaceous beds of Tibet contain several fossils identical with or closely allied to species occurring in the *Hemipneustes* and *Cardita subcomplanata* beds of Balúchistán and their Persian equivalents. Most of them are species with a fairly extensive vertical range, whose distribution is probably largely a matter of facies. In no instance, however, does the order in which they occur in Tibet result in any conflict of evi-

dence as compared with what is observed further west. The stratigraphical position of the two principal foraminifera, *Orbitoides media* characterising principally the older beds, and *Omphalocyclus macropora* the newer ones, is in accordance with their relative order in the Mari hills. There is every reason to regard the second and third massive limestones of the Kampa system, the intervening calcareous shales, and overlying Tüna limestones as the equivalent of the *Hemipneustes* and *Cardita subcomplanata* beds of Balúchistán. Their aggregate thickness, which must be nearly 600 feet, agrees remarkably with the vertical extension of the same beds along the north-western frontier of India. The overlying ferruginous sandstones very probably represent part of the Pab sandstones, or *Cardita Beaumonti* beds.

In other parts of India, where it has been possible to make a detailed examination of the stratigraphy, this ferruginous character of the beds is often a sign of hidden unconformity, the ferruginous element being of a lateritic nature, and indicating a period of continental conditions, and consequently a more or less complete interruption in the sedimentation, though the gap may not be indicated by any defect of parallelism in the successive strata. It is highly probable that the ferruginous beds of Tibet have the same signification. In order to account for the parallelism of stratification, and the curious absence of nummulites in the eocene beds overlying the ferruginous sandstone, Mr. Hayden has suggested that there may be perhaps a continuous passage from cretaceous to tertiary, and that the tertiary beds of Kampa Dzong may belong to the Lower Eocene, corresponding therefore with the Ranikot group of Sind. Mr. Hayden has suggested this explanation only tentatively, the available data being too scanty to arrive at a definite opinion. Yet, in view of the similarity with the stratigraphical conditions which have now been ascertained over a large portion of north-western India, it may be permitted to infer that the Tibetan section can receive a similar interpretation. If the ferruginous layer be taken to represent a lateritic facies indicating continental conditions, and, consequently, a gap in the sedimentation, the overlying beds need not be regarded as lower eocene, a stage of very rare occurrence in India, but can be interpreted as more probably belonging to the widespread middle eocene. The absence of nummulites may be accidental. In the Zhob district I have observed a

similar absence of these organisms in beds whose fossil contents prove to be undoubtedly middle eocene. Lithologically, the specimens of eocene rocks collected by Mr. Hayden closely resemble the *Alveolina* limestone of Balúchistán, and some of them, although without nummulites, are crowded with *Alveolinæ*. Mr. Hayden has mentioned that they contain a *Velates* apparently identical with *Velates Schmideli*. A closely related *Velates* occurs in the lower eocene Ranikot beds, but according to Messrs. Cossmann and Pissarro, who have lately studied this fossil and will shortly describe it in the *Palæontologia Indica*, it differs from the true *Velates Schmideli*. The specimens from the middle eocene of India differ from the Ranikot ones, and are very similar to, if not identical with, *V. Schmideli*. The Tibet fossil also appears to agree with *V. Schmideli*, though in all the specimens, the aperture, which furnishes the best differential characters, is concealed by the matrix; but the aboral surface, sometimes fairly well preserved, agrees with that of the middle eocene specimens rather than that of the Ranikot species. Their dimensions are also larger than those of the Ranikot fossil, which is another point of agreement with the Indian Lutetian form. Thus there is reason to believe that the eocene of Tibet corresponds with the Lutetian, and perhaps with the sub-division elsewhere known in India as the Laki group, whose age is Lower Lutetian. The Laki group is the coal-bearing division of the Indian Tertiary.

7. Southern India.

Orbitoides from the Upper Cretaceous of southern India have been figured by Stoliczka and by Kossmat. The specimens examined by Kossmat, which were not specifically identified, were obtained from Saidarampet, and the neighbourhood of Valudayur, in the post-Ariyalur beds of Pondicherri, the so-called Nerinea beds. Those examined by Stoliczka were identified by him with forms occurring at Maestricht, and appear to be identical with *Orbitoides minor* Schlumb. They were collected by H. F. Blanford at Niniyur and Chokanadapuram in the Niniyur beds of the Trichinopoli district.

Both in the Pondicherri and Trichinopoli regions, the post-Ariyalur beds have yielded *Nautilus danicus*, indicating the presence of strata of Danian age. I am not aware of any recorded observations as to the occurrence of *Orbitoides* in strata of true Danian age, if this

term be restricted to the beds characterised by *Nautilus danicus*, and newer than the last zones of ammonites and hippurites. It is probable that the Niniyur beds include strata both of Maestrichtian and Danian age. There is no information available for sorting out the fossils of either series, a difficulty which is now almost beyond remedy owing to the exhaustion of the fossil localities.

The combined thickness of the Ariyalur and Niniyur is about 900 feet. How much of this amount belongs to the Niniyur cannot be exactly determined, but whatever the proportion may be it indicates for the Ariyalur, a development closely similar to the very constant thickness of the *Hemipneustes* beds in many parts of Balúchistán, that is 500 to 700 feet As will be shown in the following chapter, the Ariyalur and Niniyur beds of southern India correspond respectively with the *Hemipneustes* beds and Pab series of the North-West. The similarity in development between the Ariyalur and *Hemipneustes* beds may be a fortuitous coincidence, yet it is worth mentioning on account of its possible connection with the widespread conditions of quiet sedimentation which prevailed at that period over such a large portion of the globe. The formations overlying the *Hemipneustes* beds and corresponding with the Niniyur are much less regular, their thickness and composition altering rapidly from one section to another.

CHAPTER II.—AGE OF THE ORBITOIDES-BEARING BED.

In Balúchistán the bulk of the fossiliferous beds in the Upper Cretaceous are of Maestrichtian age, as has been shown by Dr. Noetling in his monograph of the upper cretaceous fauna of the Mari hills. (*Pal. Ind.* Ser. XVI, Vol. I, part 3, 1897.) The documents now available as to the exact vertical range of the fossils allow a greater degree of precision in determining the age of these rocks. According to H. Douvillé *Orbitoides media* occurs, in Europe, just about the limit of the Campanian and Maestrichtian (*Bull. S. G. F.*, (4) II, page 312, 1902). We may therefore regard zone 7 of the Des valley section in which this species is particularly abundant, as the base of the Maestrichtian, while the underlying fossiliferous zones 2 to 6, may be relegated to the Campanian. Dr. Noetling has proposed a new name, "Pathanian," to include the Radiolites beds and the

Cardita subcomplanata and *C. Beaumonti* zones (*Centralblatt fur Geologie,* etc., 1903, p. 521). This grouping expresses the intimate connection of these zones in the Mari hills. The name cannot, however, be used in opposition to "Maestrichtian," for these beds include precisely the most typical horizon of the Maestricht chalk. The presence in these beds of *Sphenodiscus Ubaghsi* de Gross., a species closely related to *Sph. Binkhorsti* Böhm of Maestricht, indicates that they correspond with the last of the ammonite zones of Europe, and therefore with a part of the well-known "tuffeau" of Maestricht, the very rock from which the formation derives its name.

It is only in the Mazar Drik section that the *Cardita Beaumonti* beds of Balúchistán have yielded a fair number of recognisable fossils. Out of a total of eight fossils in zone 14 of Mazar Drik (zone of *Cardita Beaumonti*), no less than six are identical with fossils from zone 13 (zone of *Cardita subcomplanata* and *Indoceras baluchistanense*). They include one species of *Ostrea*, one of *Arca*, *Cardium loralaiense* Noetl., *Gisortia expansa* d'Arch. et Haime, and two species of *Nautilus*. The stratigraphical and palæontological connection with the underlying zone is so close, that at Mazar Drik, the *Cardita Beaumonti* zone may also be regarded as belonging to the Maestrichtian.

In many places, however, *Cardita Beaumonti* recurs at all levels of the vast series of the Pab sandstones, and it is extremely probable that the Pab series must reach into the Danian, though the characteristic *Nautilus danicus* has never been met with in Balúchistán or Sind. In an unbroken series, such as constituted by the upper cretaceous strata of Balúchistán, where the fauna of each zone graduates insensibly into that of the following one, it is difficult to draw sharp divisional lines. The precise limits must be a matter of convention, and it would seem convenient to select the species *Cardita subcomplanata* and *C. Beaumonti*, as respectively characteristic of the uppermost Maestrichtian and lowermost Danian. But the replacement of one species by the other is largely a matter of facies. The thin-shelled *Cardita subcomplanata* abounds in deposits representing indurated silt or mud. As soon as an arenaceous facies sets in, the thick-shelled *Cardita Beaumonti* appears. In Egypt, *Cardita lybica* Zittel, so closely allied to *C. Beaumonti*, that it is perhaps a mere variety, occurs both in the zone of *Indoceras Ismaelis* Zittel, a species very closely allied to *Ind. baluchistanense* Noetl., and also in the

overlying strata with *Nautilus danicus* (A. Quaas, *Die Fauna der Overwegischichten und der Blätterthone in der lybischen Wüste*, Palæont., Vol. XXX, 1902).

It is probable therefore that in Bálúchistan *Cardita Beaumonti* passes from Maestrichtian to Danian, there being no stratigraphical break between these two stages, no more than between Campanian and Maestrichtian.

The Echinoid beds of western Persia have been regarded as Campanian by H. Douvillé, which agrees with the age here attributed to the lower portion of the *Hemipneustes* beds in Balúchistán. The *Cerithium* beds which evidently correspond with the zone of *Sphenodiscus Ubaghsi* and the lower portion of the *Cardita Beaumonti* beds, have been regarded by Douvillé as Maestrichtian.

Incidentally, the presence in the Upper Maestrichtian of Persia and Balúchistán, of three intertrappean species of the Indian peninsula, *Cerithium Stoddardi*, *Morgania*[1] *fusiformis*, and *Physa Prinsepii*, enables us to fix with greater precision than had hitherto been practicable, the age of the great volcanic formation of the Indian Peninsula. (*Rec. G. S. I.*, Vol. XXXV, p. 114.)

The presence of *Orbitoides* cf. *minor* in the Niniyur beds of the Coromandel, together with *Nautilus danicus*, introduces an anomaly which can best be considered after correlating the underlying Ariyalur beds with the upper cretaceous formations of Balúchistán.

The most satisfactory zonal investigation of the Ariyalur group is that of Dr. Kossmat, based upon the field researches of Dr Warth in the Pondicherri district. (*Rec. G. S. I.*, XXX, pp. 51-110, 1897.) The Ariyalur beds of Pondicherri have been divided by Kossmat into two zones : a lower zone constituting the Valudayur series, and an upper one known as the *Trigonoarca* beds. The Valudayur beds contain the following species closely allied to or identical with Balúchistán fossils : *Alectryonia larva* Lam., *Pinna laticostata* Stol., *Macrodon japeticum* Forbes, *Desmieria divaricata* d'Orb., *Pugnellus uncatus* Forbes, *Gaudryceras Kayei* Forbes, *Sphenodiscus Shiva* Forbes.

Alectryonia larva, which is sometimes found in the lower zones of the *Hemipneustes* beds of Balúchistán, is far more abundant in their middle or upper horizons, while in the Ariyalur group; it occurs more abundantly in the upper sub-division, the *Trigonoarca* beds, than in the

[1] See footnote, page 183.

underlying Valudayur. *Pinna laticostata* or a closely related form occurs abundantly in zone 11 of the Des valley section, and zone 6 of Mazar Drik, that is in the middle horizons of the *Hemipneustes* beds. *Desmieria divaricata* is very closely related to or identical with *Desmieria pontica* d'Arch., which I have met with at Kharzán and Karu in beds corresponding with the middle or lower zones of the *Hemipneustes* beds of Des. *Pugnellus uncatus* is closely related to *P. crassicostatus* Noetl., which in Balúchistán is abundant in the uppermost ammonite zone above the *Hemipneustes* beds, but occurs also in the lower zones of the *Hemipneustes* beds themselves. A form very closely related to *Macrodon japeticum*, if not identical, is represented by some large casts occurring in horizon 11 of the Des valley. The lowermost fossiliferous zone of the Des valley section, Noetling's No 2, contains an ammonite which seems identical with *Gaudryceras Kayei*, the only doubt as to its specific identity arising from its imperfect state of preservation. One of the most abundant fossils in zone 11 of the Des valley is an undescribed *Sphenodiscus* closely related to *Sph. Shiva*, belonging therefore to the same zoological group as the south-Indian species and *Sph. lenticularis* Meek, of the "Fox Hills group" of North America, and very different from the group of *Sph Ubaghsi* and *Sph. Binkhorsti* which characterises the uppermost ammonite-bearing beds of Balúchistán, the Pyrenees, and Maestricht.

Judging from the fossil evidence above detailed, the Valudayur beds may safely be regarded as the equivalent of the lower and middle portion of the *Hemipneustes* beds in Balúchistán

In the *Trigonoarca* beds, the forms related to Balúchistán fossils or identical with them are: *Hemiaster tamulicus* Kossm (identical with *H. Blanfordi* Noetl), *Alectryonia larva* Lam., *Spondylus calcaratus* Forbes, *Macrodon Japeticum* Forbes, *Desmieria divaricata* d'Orb., *Pugnellus uncatus* Forbes Most of these forms had already been mentioned as occurring in the Valudayur beds Kossmat has shown that the faunistic connection between the Valudayur and *Trigonoarca* beds is of the closest character; it is just as close as the mutual connection between the lower and upper portions of the *Hemipneustes* beds in Balúchistán Amongst the fossils identical between the *Trigonoarca* and *Hemipneustes* beds, *Alectryonia larva* has already been referred to as particularly

abundant amongst the middle and upper zones of the latter. *Hemiaster tamulicus* which occurs in the lower and middle zones of the *Hemipneustes* beds is particularly abundant in their upper horizons. *Spondylus calcaratus* occurs in the lower and middle zones. The remaining fossils belong principally to the middle divisions.

We may conclude that the *Hemipneustes* beds are strictly homologous with the Ariyalur formation, their lower and upper portions coinciding respectively with the Valudayur and *Trigonoarca* sub-divisions.

So far as can be made out from the meagre data available, the Niniyur beds are, in part at least, equivalent to the *Cardita Beaumonti* beds or Pab sandstones. *Cardita Jaquinoti* d'Orb. is very similar to *C. Beaumonti*, perhaps identical; *Turritella elicita* Stol. closely resembles a form which frequently accompanies *Cardita Beaumonti* in north-western India. The presence of *Nautilus danicus* indicates a post-Maestrichtian age for a portion at least of the Niniyur beds. At the same time, the Pondicherri exposure has yielded a large *Cerithium* closely allied to *Campanile Ganesha* Noetl. of the middle and upper zones of the *Hemipneustes* beds. It belongs to the same group as *Campanile Morgani* Douv., *Campanile regens* Pethö, and the other large forms of *Cerithium* so common in the Maestrichtian of various lands. Like the Balúchistán species, it was originally described as a *Nerinea*, in consequence of which the uppermost cretaceous beds of Pondicherri have been misnamed the "Nerinea beds."

The Niniyur beds in the Trichinopoli exposure have yielded an *Orbitoides* which seems identical with one of the Maestricht forms. *Orbitoides* also occur in the post-Ariyalur of Pondicherri, but they are very minute and probably represent an undescribed species.

It is evident that if the Ariyalur represents the *Hemipneustes* beds and the Niniyur the *Cardita Beaumonti* beds, the intervening richly fossiliferous uppermost ammonite-bearing zone of Balúchistán and of many other countries, remains unrepresented in the south-Indian series. The attribution to this zone of the unfossiliferous sands of the Trichinopoli area affords perhaps a partial solution of this difficulty: the same horizon is unfossiliferous in several of the sections that have been studied in Balúchistán; but the presence of *Orbitoides* cf. *minor* in the Trichinopoli area, and of the large *Cerithium* of Pondicherri, suggests that if the obscure stratigraphy and

palæontology of the Niniyur beds could be worked out with greater precision than hitherto, we would find that they include upper Maestrichtian as well as Danian beds.

The age of the *Orbitoides*-bearing beds of Tibet can only be determined by comparison with other Indian sections, as they lack the class of fossils most useful for strict zonal determinations, that is ammonites, while the fragmentary Rudistæ which they contain have not been identified. The total thickness of the *Orbitoides*-bearing strata is nearly 600 feet, including the rocks described by Mr. Hayden (*Mem. G. S. I.*, XXXVI, pp. 164-169), as the 2nd and 3rd limestone, and the "Tüna limestones" intervening between the 3rd limestone and the overlying ferruginous sandstone. *Orbitoides media* extends through about 450 feet of this total thickness, from the base upwards, after which it is replaced by *Omphalocyclus macropora*. *Pycnodonta vesicularis* is found towards the upper limit of the strata with *Orbitoides media*, probably, therefore, at about the same horizon as in Balúchistán. The remaining recognisable fossils occur in the upper beds in company with *Omphalocyclus macropora*; of those which are closely related to fossils from Balúchistán, *Echinanthus* sp., and *Plicatula hirsuta* characterise the uppermost ammonite zone in Balúchistán, though the *Plicatula* appears to occur also at a somewhat lower horizon in Persia. The large *Campanile* of Balúchistán is found from the zone of *Pycnodonta vesicularis* up to the topmost layers. *Hemipneustes compressus* closely related to *H. tibeticus*, *Neithea quadricostata* occur at almost all horizons. In a general way, there is a complete harmony between the *Orbitoides* beds of the Tibetan sections and those of the north-west frontier of India, though the palæontological material is insufficient to establish a strict correspondence of the more minute sub-divisions. The total thickness is almost identical in the two regions. The 600 feet or so of *Orbitoides* beds in the Kampa-Tuna syncline may be taken roughly to correspond with the Upper Senonian, the lower half, that is Hayden's second limestone and overlying calcareous shales, representing approximately the Campanian, the remainder the Maestrichtian. As already explained when reviewing the stratigraphical data of Mr. Hayden's survey, there is reason to believe that the ferruginous sandstone represents part of the *Cardita Beaumonti* beds or Pab sandstones, and is perhaps already Danian, while the overlying Tertiary beds are in all probability middle eocene

the uppermost Cretaceous and lowermost Tertiary being absent as in so many other sections.

CHAPTER III.—ZONAL DISTRIBUTION OF THE ORBITOIDES.

In none of the localities above mentioned do we observe any single section the successive zones of which contain all the species of *Orbitoides* so far identified. Nevertheless, the correlation of the various horizons in separate localities is sufficiently clear to combine together the information conveyed by each separate section. In this way we can recognise three principal zones of foraminifera: a lower zone characterised by *Orbitoides media* alone, a middle one characterised by *Orbitoides Hollandi* and *Orbitoides socialis*, and an upper one with *Orbitoides* cf. *minor*. *Omphalocyclus macropora* makes its first appearance in the lower zone, extends throughout the middle zone, and perhaps into the upper one. The two lowest *Orbitoides* zones, roughly correspond respectively with the lower and upper portions of the *Hemipneustes* beds, and, consequently with the Valudayur and *Trigonoarca* sub-divisions of the Ariyalur, though, up to now, the Ariyalur beds have not yielded any *Orbitoides*. The third *Orbitoides* zone, that of *O. minor*, corresponds probably with the uppermost ammonite-bearing horizon, and the base of the *Cardita Beaumonti* beds. The small *Orbitoides* of the uppermost beds of Pondicherri represent perhaps a fourth horizon. In Tibet, *Orbitoides media* appears to extend higher than in Balúchistán, and is still abundant in beds which probably correspond with the second Foraminiferal horizon of north-western India. The species from Sind referred to *Orbitoides apiculata* cannot be exactly located in this scheme owing to the insufficiency of the fossil evidence in the only section where it has been observed; the strata in which it occurs probably belong to the upper part of the *Hemipneustes* beds.

PART II.—DESCRIPTIVE.

Genus ORBITOIDES d'Orbigny.

According to the diagnoses given by Schlumberger (*Bull. S. G. F.*, (4) I, p. 462-463), the genus *Orbitoides* should include foraminifera

with a median zone of rhomb-shaped chambers, on either side of which are piled up series of irregular lateral chambers, the interstices between which are occupied by variously disposed calcareous thickenings. A number of Upper Cretaceous species fit into this diagnosis, but the rhombic shape of the equatorial chambers is the only important character that distinguishes the genus thus restricted from *Lepidocyclina* in which the chambers of the median zone are hexagonal or arch-shaped. Consequently Prever has united both genera under the name *Lepidocyclina* (*Osservazioni sulla sottofamiglia delle Orbitoidinæ, Riv. It. di. Pal.*, X, 1904). If the rhombic shape of the equatorial chambers constitutes the main criterion for *Orbitoides* it excludes one of the cretaceous species, *O. socialis*, which is not readily distinguishable from an oligocene *Lepidocyclina*, especially as its megasphere resembles that of the oligocene forms.

Yet, considering that *Lepidocyclina* appears to be absent from the intervening Eocene, so far as has been ascertained in Europe, and as I have had occasion to mention in the case of India (*Rec. G. S. I.*, XXXV, p. 62), one feels rather inclined to interpret the cretaceous form as a pseudo-*Lepidocyclina*. Similar instances have been observed in many groups of fossil organisms, where certain forms reproduce the general appearance of a more ancient organism, as in the familiar instance of the cretaceous pseudo-Ceratites. At any rate, so long as the alleged existence of eocene lepidocyclines has not been substantiated, the genera *Orbitoides* and *Lepidocyclina*, whether identical or not, remain excellent zone fossils, as the two horizons in which they occur, the Upper Cretaceous and the Oligocene, are too far apart to ever give rise to any confusion.

ORBITOIDES MEDIA d'Archiac, pl. XXV, figs. 1-3, pl. XXVIII, fig. 2.

1837. *Orbitolites media* d'Archiac, *Mém. de la Soc. Geol. de Fr.*, (1) II, p. 178.

1897. *Orbitoides socialis*, Noetling, *Upper Cretaceous of the Mari Hills*, p. 8, Pl. I, figs. 1-4.

1901. *Orbitoides media*, Schlumberger, *Bull. S. G. F.* (4) I, p. 464.

The specimens from the Des valley exactly correspond with the European specimens of *Orbitoides media* described by Schlumberger in the work above quoted. The shape is lenticular with a more or less pronounced central knob on either face. The megaspheric

individuals of the Des valley (zone 7) grow to a diameter of 7 or 8 millimetres, and thickness of 2 or 3 millimetres. The microspheric individuals, which are far less numerous, are of about the same thickness, but attain a larger diameter, about 12 millimetres.

The specimens which I obtained in the Rakhi gorge on the road to Fort Munro are megaspheric individuals, of lenticular shape but much less convex than those from the Des valley. Their diameter is about 7 millimetres, but their thickness scarcely exceeds 1 millimetre. The central protuberance is less marked than in the Des specimens, but all the other characters, internal and external, are identical.

From the central granulated protuberance, a number of ridges radiate up to the margin. The intervening furrows are narrower than the ridges, and as the ridges increase in number towards the margin, their width remains about the same at all distances from the centre, the marginal ones being sometimes slightly thinner and more crowded. The increase in the number of ridges towards the margin is not obtained by intercalation as in a coral, but by means of the ridges themselves dividing into several branches. These ridges represent the calcareous thickenings that intervene between the chambers of the lateral layers. In the absence of any suitable apparatus, I have not succeeded in obtaining a satisfactory photograph of the outer surface, but the section, fig. 3, pl. I, which cuts through the lateral layers exhibits their structure with sufficient distinctness.

Mr. Douvillé to whom I showed some of these specimens noticed that the ridges are somewhat finer and more crowded than is usual in European specimens. Fig. 3, pl. VII, of Schlumberger's work above mentioned, representing a specimen from Royan, almost exactly reproduces the appearance of the Des valley specimens. They might be distinguished as a variety *tenuistriata*.

The embryonic cells in the megaspheric individuals constitute an assemblage of four chambers forming an oval-shaped group as seen in equatorial sections. The disposition appears to vary slightly according to the level at which the section is carried. It is probably in those sections which most exactly coincide with the plane of symmetry that the embryonic group appears most regular. It then consists of a central more or less rounded cell, between two semi-

lunar ones symmetrically disposed. The central cell is sometimes sub-divided by a partition coinciding with the longer axis of the ellipse constituted by the entire group. The position of this partition varies a great deal in different sections because its situation is oblique; the section may even miss it altogether. In the section reproduced in fig. 2, pl. XXVIII, which only just penetrates into the equatorial layer, this partition appears thrown quite to the edge of the embryonic group. The embryonic group is surrounded by a thick common envelope of fibrous texture.

The concentric rows of rhombic equatorial cells are very regular. At first they increase in size as their distance from the centre increases, and usually diminish again towards the margin.

In the microspheric individuals the central rows of concentric chambers in the equatorial zone are very minute, and I have not succeeded in obtaining a clear view of the microsphere.

The specimens from Tibet mostly agree in every particular with those from Balúchistán. Specimens from the beds immediately overlying the third limestone in the Kampa ridge are usually about 8 mm. in diameter and 2 mm. in thickness; occasionally they attain 11 mm. in diameter. The finest specimens are from the third limestone in the ridge close to Tüna, where the largest specimens, perhaps microspheric ones, are 13 mm. in diameter. Perfectly typical specimens occur at the very base of the second limestone in a spur 3½ miles west of Tüna, where they reach 9 mm. in diameter; a section prepared by Mr. Hayden shows the megaspheric group, the equatorial layers, and the lateral ones, all perfectly normal in their characters. At the base of the second limestone, two miles west of Kampa Dzong, the specimens are of very small size, the largest ones being only 4 mm. in diameter with a thickness of 2 mm.; they are lenticular, very convex, sometimes with a slight protuberance at the umbo; the megasphere agrees with that of *O. media*, as do the equatorial and lateral layers of chambers. These specimens probably represent a small race of the same species.

Localities and geological occurrence.—In the Des valley section this species is particularly abundant in the lower portion of the *Hemipneustes* beds, especially in zone 7 where the specimens attain their largest dimensions. A few specimens are found adhering to some

of the fossils from zone 4, but they are of smaller dimensions. The collection from Mazar Drik contains a few specimens adhering to other fossils. They are labelled "zone 6" which generally corresponds with zone 11 of the Des valley, but probably includes also a few fossils from a slightly lower horizon. The specimens from the Rakhi gorge on the road to Fort Munro are from a fairly low horizon of the *Hemipneutses* beds, but I did not work out the zonal details of the section. In Tibet, this species occurs in the Kampa-Tüna syncline where its vertical range is very extensive. It occurs throughout the divisions designated by Mr. Hayden as the 2nd and 3rd limestones, and into the lower strata of the overlying Tüna limestone.

ORBITOIDES HOLLANDI nov. sp., pl. XXVI, figs. 1, 2.

Definition.—Very thin discoidal symmetrical Orbitoides of medium size, with depressed centre, fine radiating ridges, rather large compound regularly ovoid megaspheric group, rhombic equatorial chambers in regular concentric rows.

Description.—This remarkable *Orbitoides* was discovered by Dr. Noetling at Mazar Drik in 1898. It is closely related to *O. media* and evidently belongs to the same group of forms in which the radiate disposition of the lateral calcareous thickenings might constitute a good subgeneric character.

Its remarkable shape, and the large size of the embryonic group in megaspheric individuals entitle it to specific distinction. Most of the specimens are megaspheric. Their diameter is usually 7 or 8 millimetres. The greatest thickness situated about half-way between the centre and margin is just over one millimetre. The centre instead of being raised as is usually the case in most *Orbitoides*, is depressed, so that the general shape recalls that of *Omphalocyclus.* The following diagram, fig. 2, representing a transverse section, will give an idea of

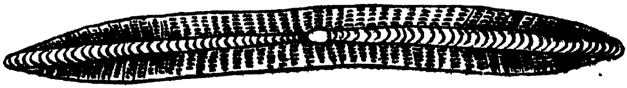


FIG. 2.—*Orbitoides Hollandi*, transverse section magnified 8 times in diameter.

the shape. Some of the specimens show a tendency to become saddle-shaped. The microspheric individuals about 15 millimetres in diameter are almost of paper-like thinness. The outer surface is very finely striated owing to the radiating disposition of the lateral calcareous thickenings. This disposition is clearly visible in fig. 1, pl. XXVI, showing a section through the lateral layers.

The megaspheric group is much larger than in the Indian specimens of *Orbitoides media*, but it resembles it in disposition. The shape and disposition of the equatorial chambers is quite similar : they are rhombic, very regularly disposed in "engine-turned" pattern, increasing in size up to a certain distance from the centre, and again decreasing rather suddenly.

Locality and geological occurrence.—This remarkable species is only known from Mazar Drik, and has been labelled by Dr. Noetling "horizon 9." It is the only fossil from that zone. Horizon 6 of Mazar Drik corresponds generally with zone 11 of Des, and represents therefore the middle portion of the *Hemipneustes* beds. Zone 9 must belong therefore to the upper part of the same beds. The horizon of *Orbitoides Hollandi* is therefore somewhat newer than that of *Orbitoides media*.

ORBITOIDES (LEPIDOCYCLINA ?) SOCIALIS Leymerie, p. XXVII, figs. 1, 2.

1851. *Orbitolites socialis* Leymerie, *Mem. S G. F.*, (2) IV, p. 191.

1902. *Orbitoides socialis* Schlumberger, *Bull. S. G. F.*, (4) II, p. 258, pl. VI, figs. 3, 6, 7, pl. VIII, figs. 15, 16.

Amongst the fossils from zone 11 of Dr. Noetling's collection from the Des valley, there is a very fine specimen of an *Orbitoides* 20 millimetres in diameter and 3 millimetres in thickness, the centre of both faces being raised into a small sharp prominence, the whole surface dotted with minute tubercles without any pronounced radial disposition, Schlumberger's fig. 3, pl. VI, in Vol. II (4) of the *Bull. S. G. F.* gives a very good idea of its appearance except for its smaller dimensions. Being the only specimen in the collection, it could not be sacrificed for the preparation of a section, but in Oldham's and Kishen Singh's collections from the neighbouring locality of Sonari there is one lot of somewhat similar specimens which neither attain the dimensions of the one above mentioned, nor exhibit such a fine state of preserva-

tion. Nevertheless they closely resemble it, and probably belong to the same horizon. I have referred them to *O. socialis.*

All the individuals examined are megaspheric. They are lenticular, about 6 to 8 millimetres in diameter, and 1 millimetre or a little more in thickness. Sometimes there is a small central protuberance. The surface is badly preserved, but the sections show numerous isolated pillars interspersed amidst irregularly polygonal chambers in the lateral layers. The chambers in the equatorial layer are much smaller than in the forms previously described, and their shape is hexagonal instead of rhombic: that is, the chambers belonging to one circular zone have a common surface of contact instead of meeting only at a point. The embryonic group consists of two chambers: a smaller spherical one, partly enclosed by a much larger one which is semi-lunar or kidney-shaped.

These specimens do not yield good sections, yet the above characters can be made out in figs. 1 and 2, pl. XXVII, and I have added for comparison a section which I prepared from a Pyrenean specimen of *O. socialis* from the "Ferme de Terne," that was kindly given to me by Mr. Douvillé. It agrees very well with the Indian specimens, the only difference being that its constituent elements, equatorial chambers, and megaspheric group are on a slightly smaller scale.

One is bound to admit that the characters of this species appear undistinguishable from those of oligocene lepidocyclines. Yet there is no doubt as to the horizon from which the specimens were obtained. They occur in the same matrix with other Cretaceous fossils, and there is no neighbouring oligocene outcrop. Moreover, this form greatly differs, specifically at least, from any of the lepidocyclines occurring in the Indian oligocene. Whether it represents their forerunner or only indicates a deceptive case of "convergence" must be left to future research.

Localities and geological occurrence.—The only specimens so far known are those above described from the *Hemipneustes* beds of the Des valley and the Sonari anticline (Lat. 21° 40′; Long. 68° 33′). The exact horizon of the latter is not known. If, as seems probable, the fine specimen from zone 11 of the Des valley in Dr. Noetling's collection belongs to the same species, its horizon is somewhat higher than that of *O. media*, and about on a level with that of *O. Hollandi.*

ORBITOIDES APICULATA, Schlumberger, pl. XXVIII, fig. 3.

1861. *Orbitoides Faujasi*[1] p. p. Reuss, *Sitz. der math.-nat. Class. der kais. Ak. d. Wiss., Wien.* XLIV, p. 309.

1901. *Orbitoides apiculata* Schlumberger, *Bull. S. G. F.*, 1 (4), p. 465, pl. VIII, figs. 1, 4, 6; pl. IX, figs. 1, 4.

The specimens which I have referred to this species are those found in the lowermost visible bed of the cretaceous rocks of the Laki range in Sind at Barrah hill. They are embedded in a very hard limestone, and sections along definite directions are difficult to obtain. The specimens attain 6 to 8 millimetres in diameter, and 1 to 2 millimetres in thickness. Transverse sections visible in the rock show that the shape is unsymmetrical, the lateral layers being more developed on one side than on the other. The calcareous pillars are distributed evenly amidst the polygonal lateral chambers, without any definite radial disposition. The megaspheric group consists of several chambers arranged somewhat as in *O. media*. The equatorial chambers are regular and rhombic.

All these characters agree sufficiently with those of *O. apiculata* to justify a reference of the specimens to that species.[2]

The above characters have been made out from the details partially exhibited by several individuals. I could not obtain a section showing them all at once. The one represented in fig. 3, pl. XXVIII, though unsatisfactory, is the only one that lends itself to photographic reproduction.

Locality and geological occurrence.—The occurrence of these specimens at the visible base of the Cretaceous of the Laki range indicates that these strata, contrary to a previously expressed opinion (*Mem. G. S. I.*, XVII, p. 33), contain no beds of greater age than

[1] By adhering strictly to rules of priority, the name of this species should perhaps be *O. Faujasi* Reuss (*non* Defrance). Although Reuss (*Die Foraminifera der Kreidetuffs von Maastricht*, 1861) has not clearly distinguished between the two Maestricht species, yet his diagnosis indicating that some of the specimens are unsymmetrical shows that his observations refer partly to the larger of the two species, the one subsequently distinguished as *O. apiculata* by Schlumberger.

[2] A second species of the same group of unsymmetrical *Orbitoides* has been described under the name of *O.* (*Silvestrina*) *van den Bröcki*, by Prever, in "*Osservazioni sulla sottofamiglia delle Orbitoidinæ*" (*Riv. It. di pal.*, X, 1904). Unfortunately this work is not available in the Library of the Geological Museum at Calcutta.

Maestrichtian. The absence of any other recognisable fossils precludes a closer reference to any special zone. In the overlying massive limestone, Dr. Blanford found one fragment belonging to the family of the Hippuritidæ. The only horizon at which this group of fossils is common in Balúchistán is Noetling's zone of *Radiolites Musehketoffi* just above the *Hemipneustes* beds. If this is the age of the massive limestone at Barrah hill, the *Orbitoides* would belong to the uppermost part of the *Hemipneustes* beds. Dr. Blanford's specimen of Hippurite cannot be traced in the Survey collection, and I failed to discover another when I visited Barrah hill.

ORBITOIDES MINOR, Schlumberger? pl. XXVIII, fig. 1.

1873. *Orbitoides Faujasi* Stoliczka, *Cretaceous fauna of southern India*, Vol. IV, p. 193.

1901. *Orbitoides minor* Schlumberger. *Bull. S. G. F.*, (4) 1, p. 466, pl. VIII, figs. 2, 3, 5; pl. LX, figs. 2, 3.

Dr. Stoliczka identified the specimens from the Niniyur beds in the Trichinopoli district of Southern India with the Maestricht forms described by Dr. Reuss, partly on account of the unsymmetrical shape of some specimens, as shown in figs. 3 and 4, pl. XII, in the Palæontologia Indica. Judging from the available remnants of H. F. Blanford's collection, this is an accidental character, at least in specimens of the small size of the one shown in fig. 3 of Stoliczka's description. Only as Stoliczka mentions specimens of 8 millimetres in diameter, that is, double the size of those now preserved in the collection, it is quite possible that at Niniyur, as at Maestricht, there exist two different species.

The specimens now available are small, symmetrical, regularly lenticular with very slight convexity. None of them show the central protuberance mentioned by Stoliczka as occasionally present. Their diameter is 3 or 4 millimetres, rarely 5, their thickness 1 millimetre or less. In outer appearance the specimens are identical with the ones from Maestricht shown in Schlumberger's figures above referred to. The lateral layers exhibit the usual isolated pillars and polygonal chambers. I have not succeeded, with the small amount of material at my disposal, in obtaining a clear view of the megasphere. The equatorial layer is beautifully shown in the original of fig. 4, pl. XII, of

Stoliczka's monograph. A photograph of this section is herewith published (pl. XXVIII, fig. 1).[1] The chambers in the equatorial layer are very regularly disposed, and of rhombic outline. The cavities in this specimen have been filled with a ferruginous red material, in consequence of which the communications between the chambers of successive concentric zones are very clearly exhibited, as has been noticed by Stoliczka. The following sketch (fig. 3) illustrates this structure.

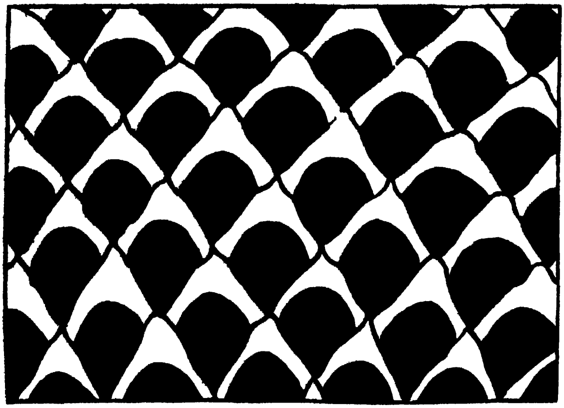


FIG. 3.—Disposition of equatorial chambers and canals in *Orbitoides cf. minor*.

The specimens which I obtained from the Pab sandstones of the Suleimán range exhibit the same characters, but in these also I have failed to detect the megasphere.

Nevertheless, in the specimens both from southern and from north-western India all the other characters agree so well with those of *O. minor* of Maestricht, that the identification here proposed may be regarded as sufficiently secure.

Localities and geological occurrence.—The localities at which this species has been obtained are Niniyur and Chokanadapuram in the Trichinopoli district and the Pab sandstones of the Suleimán range near Fort Munro. The specimens from southern and northern India both agree in geological age in so far as they have been found

[1] Dr. Stoliczka's section is a miracle of skill. It dates from a time when the making of thin sections of rocks and minerals was little practised, and has been prepared without being attached to a glass support. It is of paper-like thinness, and beautifully regular. To ensure its better preservation, I have had it mounted on a glass slide, in the manner now generally in vogue.

in rocks respectively newer than the Ariyalur series and the *Hemipneustes* beds. In neither instance, however, do we know their exact position with respect to the newest of the ammonite zones, the zone of *Sphenodiscus Ubaghsi* and *Indoceras baluchistanense* which is newer than the upper limit of the *Hemipneustes* beds of Balúchistán, and probably therefore than the upper limit of the Ariyalur of southern India. The ammonites of this zone have not yet been detected either in southern India or in the Suleimán range, while in the Mari hills and in Jhalawán, where the zone is so well developed, it does not contain any foraminifera. As *Orbitoides minor* is very common in this particular horizon at Maestricht, this is probably also the geological age of the same fossil in India. If such is the case, we must, as has already been pointed out, regard a portion of the Niniyur series as Maestrichtian.

ORBITOIDES sp.

1897. *Orbitoides* sp. Kossmat. *Rec. G. S. I.*, XXX, p. 107, pl. X, figs. 8-10.

The minute Orbitoides from the post-Ariyalur of Pondicherri, which have been figured by Kossmat, do not belong to the same species as those figured by Stoliczka. They are of very small dimensions, symmetrical, lenticular, and very convex. Their diameter is less than 2 millimetres. The only available specimens are the sections prepared by Dr. Kossmat, in which the megasphere appears small and globular, and is surrounded in the equatorial layer by very small chambers which are not disposed very regularly, though it is uncertain how far this may result from the degree of obliquity of the sections cutting through them at haphazard, as all the specimens are embedded in the rock. The shape tends to hexagonal. The characters of the lateral layers in tangential section do not show very clearly in any of the available slides. In transverse sections the lateral layers appear numerous, thin, regularly piled upon one another, traversed at equal intervals by numerous thin calcareous pillars gradually widening from the megasphere to the outer surface. The disposition of the pillars and lateral chambers appears therefore to be such as is usually seen in most species of *Orbitoides*.

These specimens probably represent an undescribed species for which the name *Orbitoides minima* might be suggested, but the available material is not sufficient for a complete diagnosis.

Localities and geological occurrence.—The specimens figured by Dr. Kossmat were collected by Dr. Warth at Saidarampet and at 1½ mile S.S.E. of Valudayur, in the post-Ariyalur beds of the Pondicherri region. According to Dr. Warth, small foraminifera are particularly abundant in a hard calcareous sandstone that underlies the soft sandstones which have yielded the few specimens of larger fossils (*Rec. G. S. I.*, XXVIII, pp. 18, 19). Dr. Kossmat mentions, however, that the specimens figured by him are from the matrix of the larger fossils. It is doubtful therefore whether they are the same as those referred to by Dr. Warth. They may belong to a more recent zone than any of the other species hitherto described, but in the uncertainty that prevails regarding the stratigraphy of the Niniyur formation, this cannot be exactly ascertained.

ORBITOIDES sp. indet.

Another minute *Orbitoides* occurs in the *Lithothamnion* limestone of Tibet. Its greatest diameter does not exceed 1·5 mm. It is lenticular, convex, with a sphērical megasphere, the details of which have not been recognised. The chambers in the equatorial layer are rhombic, while the lateral layers exhibit numerous star-like pillars disposed as in *O. minor*, and resembling those observed in the specimens from Niniyur and from the Suleimân range referred to that species. The form is evidently allied to *O. minor*.

Genus OMPHALOCYCLUS Bronn.

As has been shown by Douvillé (*Bull. S. G. F.* (4) II, p. 307, and *Mission Scientifique en Perse, Paléontologie*, p. 366), *Omphalocyclus* may be regarded as an *Orbitoides* in which the lateral layers have not been developed. All the specimens hitherto known from various localities seem to belong to one species, *O. macropora* Lam.

OMPHALOCYCLUS MACROPORA Lamarck, pl. XXIX, figs. 1-3.

1816. *Orbulites macropora*, Lamarck, *An. sans vert.*, II, p. 197.
1897. *Orbitolites macropora*, Noetling, *Upper Cretaceous of the Mari hills*, p. 8, pl. I, figs. 5-6.
1907. *Orbitolites macropora*, Hayden, Central Tibet, *Mem. G. S. I.*, XXXVI, p. 166.

The numerous specimens from the Mari hills and Jhalawân agree entirely with those previously described from various other localities,

The microspheric individuals, which are very plentiful, are discoidal and thickest at the margin. Their diameter reaches 12 millimetres, their greatest thickness about 2 millimetres. The chambers are rhombic, increasing considerably in size up to the margin. The microsphere is minute and difficult to detect, a spiral arrangement of the earliest zones being obscurely indicated. The regular concentric disposition sets in at a very early stage. Fig. 4 illustrates, with a magnification of 80 diameters, the disposition of the innermost chambers as far as can be detected in the clearest available section.

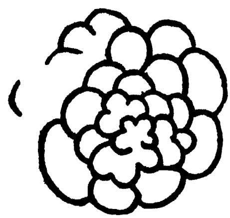


FIG. 4.—Innermost chambers of a microspheric specimen of *Omphalocyclus macropora* magnified 80 times in diameter.

The megaspheric individuals are about as thick as the microspheric ones, but their diameter does not exceed four or five millimetres. The megaspheric group is large and ovoid, and sub-divided somewhat in the same manner as in *Orbitoides media.* Its appearance varies a great deal according to the level at which it is cut through by the sections. The zones of serial chambers that immediately surround the megasphere are rather irregular.

As this account is going to the press, I have received, through the courtesy of Professor A. Silvestri, a copy of his valuable Memoir on the occurrence of *Omphalocyclus macropora* in the Palermo region.[1] One of the illustrations representing a megaspheric individual from Maestricht exhibits the constitution of the megaspheric group more clearly than I have been able to show it in my photographs of Indian specimens. I have therefore had part of it here reproduced in

[1] *L'Omphalocyclus macropora* (Lamck.) a Termini-Imerese (Palermo), *Atti della Pontificia Accademia Romana dei Nuovi Lincei,* anno LXI, Sessione del 15 Decembre 1907, pp. 17-26.

outline. Professor Silvestri is the first observer who has recognised the dimorphism of *Omphalocyclus*.

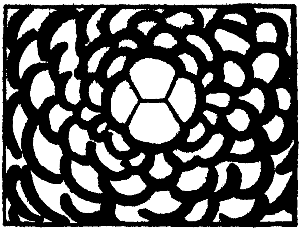


FIG. 5.—Innermost chambers of a megaspheric individual of *Omphalocyclus macropora* from the Maestrichtian of Maestricht, magnified 22 times, after A. Silvestri.

The specimens from Tibet are of small dimensions, usually about 5 mm. in diameter. They agree in every respect with those from Balúchistán.

Localities and geological occurrence.—This species has been met with at Des and Mazar Drik in the Mari hills, and at many localities in Jhalawán. In the latter region, it is the only *Orbitoides* (*sensu lato*) so far met with. It occurs at all horizons of the *Hemipneustes* beds, except the lowermost; but it is especially large and abundant in the upper zones. It is also found in the *Radiolites* beds of the Des valley section, where it ranges from zone 7 to zone 19, the finest specimens occurring in zone 16. It also occurs in Tibet, in the middle zone of the Túna limestone.

SUMMARY AND CONCLUSIONS.

The genus *Orbitoides* is represented in the Upper Cretaceous of Tibet, and of north-western and southern India, the north-western district and Tibet also containing the genus *Omphalocyclus*

Most of the species are identical with European forms and succeed one another in the same order. The correlation inferred from a study of these foraminifera coincides with the evidence furnished by the distribution of the ammonites, and the value of both groups as a guide to geological age is thereby mutually enhanced.

In Balúchistán, two main divisions are present, a lower calcareous one known as the Hemipneustes beds, and an upper one consisting

mainly of sandstones and olive-coloured shales with a great abundance of volcanic material. Two divisions are also recognisable in western Persia, the Echinoid beds coinciding with the Hemipneustes beds, and the Cerithium beds corresponding with a part of the overlying group. The Hemipneustes beds are mainly Maestrichtian, their base only belonging to the Campanian. The base at least of the overlying group, containing the newest ammonite zone, is Maestrichtian, but its upper portion probably reaches into the Danian. These upper Maestrichtian, and probably Danian, beds correspond in age with the Deccan Trap of the peninsula.

In southern India, the Ariyalur beds correspond with the calcareous Hemipneustes beds of Balúchistán, the Niniyur beds with the overlying sandstones and shales. The duration of the Ariyalur series coincides with the entire range of the Hemipneustes beds. Of the two sub-divisions that can be recognised in the Ariyalur series of the Pondicherri district, the lower one or Valudayur corresponds with the lower and middle portion of the Hemipneustes beds, while the Trigonoarca beds correspond with their upper portion. The lower part of the Valudayur may therefore be regarded as Campanian, its upper part as Maestrichtian; the Trigonoarca beds are Maestrichtian. The base of the Niniyur is probably of Maestrichtian age, but the presence of *Nautilus danicus* indicates that the upper part of the formation is probably Danian.

In the Pusht-i-Koh of northern Persia, throughout Balúchistán, and in the northern part of the Coromandel, the base of these formations rests directly upon lower Cretaceous or pre-Cretaceous rocks. This widespread overlap agrees with the evidence furnished by many lands as to an extensive marine transgression that commenced in Campanian times. Sedimentation continued uninterrupted throughout the Maestrichtian and into the Danian in places where the section is most complete. Another gap then intervenes, and the next strata belong to various horizons of the lower or middle eocene.

Amongst the species of *Orbitoides* identified in these upper Cretaceous beds, *Orbitoides media* occupies the lower part of the Hemipneustes beds and ranges through strata whose age may be referred to the uppermost Campanian and lowermost Maestrichtian. In Tibet its vertical extension is very extensive, and it probably ranges through the whole Campanian and a considerable part of the Maestrichtian. *Orbitoides socialis* belongs to the middle or upper part of

the *Hemipneustes* beds, apparently therefore to the middle Maestrichtian; and *O.* cf. *minor* is found only in strata of later age than the Hemipneustes and Ariyalur beds, and probably belongs to the uppermost Maestrichtian. *Orbitoides apiculata* probably belongs to the upper part of the Hemipneustes beds of middle to upper Maestrichtian age. The vertical distribution of these species and their succession agree with what has been observed in Europe.

A new species of middle Maestrichtian age has been described as *Orbitoides Hollandi.* The minute *Orbitoides* of the post-Ariyalur beds of Pondicherri belong probably to an undescribed species for which the name *Orbitoides minima* is proposed, and are perhaps of Danian age.

Omphalocyclus macropora occurs, in Balúchistán, throughout the greater part of the Maestrichtian. Its range in that region is therefore more extensive than has hitherto been observed in Europe where it is mostly confined to the upper Maestrichtian, to which it also seems restricted in Tibet.

LIST OF ILLUSTRATIONS

PLATE XXIX.—*Omphalocyclus macropora* Lamarck. Figs. 1 and 2, megaspheric individuals. Fig. 3, microspheric individual, Des valley (horizon 4 of Oldham), coll. R. D. Oldham and Hira Lal.

All the above sections are magnified 15 times in diameter.

FIGURES IN THE TEXT.

TWO CALCUTTA EARTHQUAKES OF 1906. By C. S. MIDDLEMISS, B.A., F.G.S., *Superintendent, Geological Survey of India.* (With Plate 30.)

Introduction.

DURING the latter part of the year 1906, Calcutta and the neighbouring parts of the Gangetic delta experienced two smart earthquake shocks, one on 29th September and the other on 6th December, of which the former was the more noticeable. Unlike the great earthquake of 1897 and others which have periodically been felt in Calcutta, but which originated away in the hilly areas to the north-east, these two shocks were much more local in their manifestations, and must have had their origins either within the delta or under it. Although doing comparatively little damage (the latter especially), their significance lies in the conclusion that either the delta itself, or the substructure of hard strata underlying it, is still capable of generating occasional earthquakes, and cannot be regarded as having attained that degree of stability and immunity from shocks so desirable in the neighbourhood of an important centre such as Calcutta.

Earthquakes having a local origin of this kind, though they have not been experienced during recent years, were more common between 1845 and 1869, when 14 were recorded.[1]

Earthquake of 29th September 1906.

Issue of earthquake question-forms.

The more prominent of this pair of earthquakes, that of 29th September, in view of the fact that it caused slight damage to many Calcutta buildings, was deemed of sufficient importance for the issue of earthquake forms to officials and others within the affected area. The following account is an attempt to summarise the infromation furnished by those forms.

Seismograph record at Alipore Observatory.

The shock was registered on the Milne seismograph at the Alipore Observatory,[2] Calcutta. The trace is described as beginning (commencement of preliminary tremors) and attaining its maximum at the same

[1] See Catalogue of Indian Earthquakes by Dr. Oldham, *Mem. G. S. I.*, Vol. XIX, Part 3.

[2] See Monthly Weather Report, September 1906.

moment, namely, 5 hours 8·7 minutes G. M. T. which = 11 hours 2 minutes 3 seconds Calcutta time. Its duration is given as 12 seconds, but its amplitude can only be known to have been relatively very great, inasmuch as the boom moved through the whole breadth of the trace.

Outer limits of the shock.

The outer limits of the felt shock coincided roughly with the outer dotted line on the map. It includes the districts of Calcutta, the 24-Parganas, Howrah, Hugli, Bardwan, Nadia, Jessore, Khulna, Faridpur, Pabna, Rajshahi, Murshidabad, and Birbhum; and parts of Midnapur, Bankura, and Tippera districts. The unmentioned districts in Bengal and Assam surrounding this area all furnished forms declaring the shock not to have been felt there. The land area of the felt shock is therefore very roughly about 50,000 square miles.

Time of main shock.

The majority of the better authenticated accounts agree in giving the time of the main shock as shortly after 11 A.M. (Calcutta time); but a few other accounts of felt shocks on the same day, some being far away from the Gangetic delta, give discordant times between 7 and 8 A.M. One or two of these may indicate foreshocks or other shocks having some obscure relation to the main shock, but many of them belong to a separate disturbance originating much further north, whilst one at least from the Assam area is evidently more rationally to be understood as connected with the after-shocks of the 1897 earthquake, whose epicentral area does not yet seem to have reached absolute quiescence, judging by the seismoscope records of Shillong and Dambu, which still continue to show a periodic sequence of minor quakes dating from 1897.

Order of examining the evidence: scale of intensity used.

We have the most complete evidence regarding the shock from Calcutta, which was shown to have been perhaps as severely shaken as any part of the affected area. I propose therefore to begin with the description of Calcutta, and afterwards go on to the surrounding districts which will be taken up according to their proximity to Calcutta, and moving in circles round it as a centre. Each locality is numbered and referred to by a corresponding number on the sketch-map accompanying this article. At the end of each description an attempt has been made to estimate the intensity by numbers in terms of the Rossi-Forel scale; and these numbers in Roman character are found on the map following the number indicating the locality.

The highest number, VI—VII (being nearer VII than VI), is one which indicates an intensity just falling short of serious damage and panic.

In the attempt to apply the Rossi-Forel scale to intensities below the point where damage to buildings begins to be serious, it was found that the varying architecture and conditions of life in India did not allow such a fine division as is given in the Rossi-Forel scale. This is principally due to the impossibility of correlating such purely European standards as ringing of church bells and house bells, swinging of chandeliers, disturbance of furniture, doors, windows, and cracking of ceilings. I have therefore grouped intensities II and III, IV and V, and VI and VII together in pairs, as was done by Mr. Oldham in his description of the 1897 earthquake, connoting them as follows :—

Intensities.	Definition applicable to India
II—III Rossi-Forel	Felt by a few sensitive people lying down, or favourably situated.
IV—V Do.	Generally noticed, no damage.
VI—VII Do.	Universally felt. Disturbance of furniture and loose objects. No damage to buildings except in rare instances to brick-built structures.

The higher intensities of VIII, IX, and X were not experienced in the present earthquake.

Reasons for giving details.

It may be thought and commented on by some that the details which follow are a monotonous series of uninteresting, and frequently similarly expressed experiences. This is in a great measure true; but the reason for putting them on record is to be found in the fact that they are the only evidence we have or can ever have of a shock which came very near to being disastrous to the chief town in British India. If not recorded now, their details must pass into oblivion, since the evanescent character of most earthquake effects always precludes a re-survey of an area affected by a seismic disturbance.

(1) Calcutta and 24-Parganas.

The Very Reverend Father Lafont, C.I.E., S.J., late Professor in St. Xavier's College, at 12, Park Street, Calcutta, kindly sent us the following particulars: Time about 11-2 A.M. (Calcutta time), by a chronometer watch verified by gun-time. There were distinct preliminary tremulous vibrations, as if a heavy waggon was passing below the room (second storey), followed by a smart shock with ominous creaking of the furniture of the room; and after an interval of 6—7 seconds by another similar shock, less sudden but quite as smart. Direction N. by E. (the direction of the building), observed by water in basin in slab of marble. Then followed a third oscillation weaker than the other two shocks. The water gradually oscillated at right angles to its previous direction. A heavy arm-chair in which observer was sitting was shaken, and other furniture creaked. A rumbling sound preceded the first shock and lasted fully 5—6 seconds

Similar information was furnished by the Reverend Father J. van Neste, S.J., and by Messrs. C. Needham and L. J. Maguire of St. Xavier's College, with the exception that the latter gave the directions as: 1st shock E. by N. to W. by S., 2nd and 3rd shocks E.—W.

Indian Museum: Industrial Section.

Mr. I. H. Burkill kindly furnished us with the following notes from the Industrial Section of the Indian Museum, Calcutta, compiled by Mr. Vieux: "The earthquake which took place on the 29th September appeared to run along the length of the building, judging from the position in which the bottles fell from their stands in the show-case. For instance, the wine case had 14 bottles broken in it. Of this number, 6 were on stands east of the case, and 8 on the west. The bottles containing tea which fell were all facing west. The following is a list of the damage done:—

Broken . .	14 bottles containing	wines.
	6 " "	tea.
	4 " "	syrup.
	2 " "	chutney.

Two slight cracks in the north wall of the Art Gallery, both over the eastern half of the windows whence they severally start. There are also two cracks on each side of King Thebaw's throne in half-brick walls recently erected."

Report on Public Buildings in Calcutta.

The Superintending Engineer, Central Circle, Calcutta, reported the following damage done to buildings in Calcutta under the several Executive Engineers of the circle :—1st Calcutta Division : High Court buildings. Two pillars of the south verandah, 1st floor, immediately adjoining the tower, have cracked badly. The piers having been reported to be unsafe, the necessary steps to strengthen them were taken in hand.—Writers' Buildings, Lord Bishop's Palace, Veterinary College, Belgatchia. Old cracks re-opened in several places, mainly to arches of the above buildings, but none of them were of a serious nature.—2nd Calcutta Division: Presidency General Hospital. Slight damage was done to the Medical Subordinates' quarters, and a crack in the bridge of the main block re-appeared. One of the out-houses attached to the third-class quarters was cracked in one place where there was already a crack from settlement.—Alipur Central Jail. Cracks appeared in three flat arches and in five semicircular arches, but they were slight.—The Police Court, Sealdah ; The Superintendent's Residence, Campbell Hospital ; Intally Police Station ; Albert Victor Leper Asylum ; Superintendent's Residence, Gohra ; Ballygunge Police Station ; The Madrassa College ; Police Commissioner's Residence ; St. James's Church and Parsonage. Hair cracks appeared in the walls and arches of the above, but they were not dangerous to the structures.—Judges and Munsiffs' Court, Alipur. A few arches are cracked in the former, or rather old cracks in the arches are re-opened. In the latter some verandah arches in the new extension are cracked.—Upper Military Orphan School at Kidderpore. A number of arches and walls showed cracks. They are not serious, but are small and numerous, most of them being old cracks re-opened.—Watgunge Police Station. In this building some arches are cracked, none being serious. The brick-work of the building is poor, and especially in the semicircular arches it was noticed that bricks had become rather loose. The bricks are thin and of small size.—St. Stephen's Church. A vertical crack appeared at the junction of the tower, and extends almost the whole height of the building, as well as at the junction of the roof of the nave with the tower wall, but the crack is very slight.—Lower Military Orphan School. A slight crack appeared at the junction of two walls which appear to have been built at different times.—Garden Reach

Police Station. This old building suffered similarly to the one at Watgunge.—Mominpore Morgue. Hair cracks appeared in almost all the verandah segmental arches.—Ballygunge Out-Post. Only two arches of the cook-room slightly cracked.—Civil Engineering College, Sibpur. The new barracks did not suffer at all. The Professors' quarters in the western barrack suffered most; though all the cracks in this building are old ones that have re-appeared. Though conspicuous outside they show very slightly inside the building. In other residential and workshop buildings old cracks re-appeared, none being serious. Neither to the Belvedere buildings nor to those of the Royal Botanic Gardens at Sibpur has there been any damage.—3rd Calcutta Division: Medical College Hospital. Slight cracks appeared in many of the arches, chiefly in the centre portion of the building, none being serious, and most being old cracks due to the 1897 earthquake.—Medical College (old) buildings. Four arches on the south faces have cracked, one flat arch being very badly damaged. Three other arches are also slightly cracked. One on the north and the other on the east are badly cracked.—Principals' quarters. Six or seven arches slightly cracked.—Eye Infirmary. The old crack at the north-west corner has been re-opened. No new cracks are visible.—Eden Hospital. Slight hair cracks in a few arches are alone visible.—Pathological block. No new cracks appeared, but some previous cracks in the west wing arches were made more prominent.—Bethune College. One slight crack in south-east corner of small building appeared.—Presidency College. Some old cracks re-appeared.—Special Works Division: No appreciable damage appears to have been caused to the buildings in this division.

Other Calcutta reports.

Nalin Prokash Gangoly, Honorary Magistrate, at "The Prasad," Calcutta, reported as follows: Time 11 A.M., time-piece immediately compared with the Tagore Castle clock. One tremulous vibration before the shock. One principal shock. Direction at first N.E.—S.W. by water in bath tub. Afterwards E.—W. Distinctly felt. No sound.

Girindra N. Datt at Sat Bazar, Calcutta: Time shortly after 11 A.M. Two shocks with interval of 1 or 2 seconds. Tremulous vibrations felt before and after. Direction E.—W. Flagsticks fell down, Pendulum clock stopped. Almirah rocked. North and south wall cracked longitudinally. Rumbling sound during the shock.

Abbilas Chandra Mukerjee, Deputy Magistrate and Deputy Collector, at Calcutta: Time 11-3 (Calcutta time) by clock regulated by gun-time the day before. One smart shock and a feeble return shock. No tremulous vibrations felt. Direction W.—E. by water in a cistern. A very distinct shock nearly upsetting observer. No sounds or other effects.

Bijaykumar Ganguli, Deputy Magistrate and Deputy Collector, Bangsidharpur, 24-Parganas: Time 11-10 A.M. (Calcutta time). Two principal shocks at interval of 3—4 seconds, the first being prominent and the second a very mild one. Felt slight vertigo. No sound or other effects.

Summary.

Summing up the evidence for Calcutta and the 24-Parganas we may estimate the intensity as VI—VII, being nearer VII than VI. The usual sounds were generally heard before and during part of the shock. The time was about 11 hours 2 minutes A.M. (Calcutta time). There appear to have been tremulous vibrations both before and after, with two main shocks between at intervals of about 7 seconds.

(2) Midnapore district.

From the rather large district of Midnapore, lying to the west of 24-Parganas, only one earthquake form has been received:—

From Pitamber Bhattacherya of Ghatel: Time about 10 A.M. Two shocks. Direction S.—E. Distinctly felt. The whole building trembled. No sound. Water of tank moved from S.—E. to N.—W.

From this, in the absence of any special explanation, and from other considerations, we must believe that the shock was not universally felt throughout Midnapore district. The intensity at Ghatel appears to have been as much as IV—V, but outside this area it must have dwindled down to at least II—III, if the absence of reports is to be relied on as equivalent to an absence of evidence.

(3) Howrah district.

The district of Howrah lies near to Calcutta on the western side of the Hugli river. Only the two following reports have come to hand, from which an intensity of IV to V may be inferred:—

From Ganendra Nath Ganguly, District Engineer, Howrah town: Time 10-55 A.M. Two shocks. Distinctly felt. No sound or other effect.

From Jogendra Kumar Sen, B.L., Pleader, Uluberia: Time

about 10-30 A.M. Two principal and prominent shocks were slightly felt. Tremulous vibrations before and after for a few seconds. Direction S.W.—N.E. An indistinct sound.

(4) Hugli district.

From the Hugli district, which lies north-west of Calcutta, 14 forms have been received, the facts of which can best be illustrated in abular form. With reference to the time of the shock, the evidence is not sufficiently precise to be worth repeating in detail. In the first place the standard of time is not given except in two cases, and for the rest the recorded times vary from 10-30 to 11-30 A.M. Although the average of all the observations comes out 11-7, it is felt that no reliance can be placed on them to even within 15 minutes. Ten observers describe the shock as "distinctly felt" and four as "slightly."

Locality and observer.	Number of shocks, direction and duration.	Sound.	Other effects.
Mamudpur—			
Jodu Nath Das	One. N.—S. 10–12 seconds.	None . .	None.
Haripal—			
Banka Behary Ghose.	One . . .	...	...
Kristanagore—			
Hari Pada Ghose and two other observers.	One . . .	...	...
Serampore—			
Harif Ullah .	One. E.—W. .	None . .	..
Tarkeswar—			
Sarat Chandra Ghosh.	One followed by tremulous vibrations for a few seconds.	None . .	None

Locality and observer.	Number of shocks, direction and duration.	Sound.	Other effects.
Chinsurah—			
Mohendra Nath Bhuttacharjee.	One. S.—N. One second.	Like roaring .	Cracks in arch of room.
Panduah—			
Saroda Prasad Roy.	One. N. E.—S. W. Very brief.	Rumbling heard before.	None.
Mirbir –			
Bhagabati Kumar Chaudhuri.	One. 5 seconds .	Sound like "goom" 3 seconds before shock.	Plaster fell from ceiling.
Ghutiabazar—			
Sahadev Mallik	One, followed by tremulous vibrations for 5—6 seconds. E.—W.	Heavy rolling sound.	Observer's heart went pit-a-pat, and his body underwent a severe shaking.
Chinsurah—			
Hira Lall Seal	One. N.—S. .	Rolling sound, like motor car, a few seconds before.	Whole building vibrated smartly.
Chinsurah—			
Mahadeh Dhur	One. N.—S. Tremulous vibrations after for 1 minute by water in tank.	None .	None.

Locality and observer.	Number of shocks, direction and duration.	Sound.	Other effects.
Chinsurah –			
Gocool Chunder Dhur.	Two. With interval of 1 second. N.—S.	Whistling sound before.	None.
Somrah—			
Chandra Narayan Roy.	Two, at interval of 2 seconds. Tremulous vibrations after for 5 seconds. E.—W.	Like rushing wind.	...
Chanditolah—			
Baikuntha Nath Chakerbutti.	Two, at interval of 2 seconds. E.—W.	None . .	None.

Most of the above localities are from the central and eastern parts of the Hugli district. There seems to be a slight increase in the effects in the more easterly parts, but the difference does not amount to much. A general estimate of intensity for this part of the district is VI to VII.

From the Bardwan district there are only three accounts.

(5) Bardwan district.

Mr. W. Ash, Telegraph Master, gave the time as 10-38 standard time, which corresponds to 11-1-21 Calcutta time. Direction N. E.—S. W. Duration 2 to 3 seconds. He felt as if rocked on a table. The punkah, which could swing east-west, dashed against the south wall in a south-west direction. The shock was a strong one. There was a slight buzzing sound as of distant thunder.

Captain C. Weinman, I.M.S., also at Bardwan, gave the time as 11-3 A.M. local time, and the direction E. S. E.—W. S. W., whilst the Collector of Bardwan gave the direction as probably E.—W. and the duration a few seconds.

The paucity of the accounts from this district suggest an intensity of IV to V as perhaps sufficient, although Mr. Ash's details indicate a somewhat higher value.

Nadia district, which stretches away to the north-north-east of

(6) Nadia district.

Calcutta, has furnished five earthquake forms, some of which indicate as severe an intensity as Calcutta. The results are arranged in tabular form. The times vary nearly as widely as in the Hugli district, and are unreliable.

Locality and observer	Number of shocks, direction and duration.	Sound.	Other effects.
Santipur—			
Bhujendra Nath Mukerjee, Sub-Divisional Officer.	Two. N.—S. . .	Preceded and accompanied by rumbling sounds.	Top of east wall of kitchen (an old building) slightly cracked.
Ranaghat—			
Nogendra Nath Mukerji, B.L., Pleader.	Two, with an interval of 2 seconds W.—E.	Like distant thunder immediately before and during the shocks.	People ran out of their rooms in fear. Roof of a verandah came down.
Chuadanga—			
Kherode Chandra Choudhuri.	Tremulous vibrations side to side, followed by three shocks.	...	The roof made a slight noise.
Chuadanga—			
Abdur Rahim Mullik, Muktiar.	One shock. ? N. E. —S. W.	None .	Clothes hanging in room swung.
Kushtia—			
Satamanyn Mukerji, Sub-Deputy Collector.	Two. E.-W. The first lasted 3 seconds, the last 6 seconds and more intense.	None . .	...

The intensity is described as "distinct," "slight," and "very slight" as we proceed north-north-east from the neighbourhood of Santipur and Ranaghat in the direction of Chuadanga and Kushtia.

We may therefore estimate it roughly at VI to VII in the south of the district, and IV to V in the more northern parts.

(7) Jessore district.

Jessore lies to the north-east of Calcutta. Only two forms have been received from which to draw conclusions. Both indicate an intensity below that of Calcutta, but between themselves but little difference in the violence of the shock can be made out. They are as follows:—

Charu Chandra Rai, of Bangaon: Time 11-2 A.M. (local time). Some preliminary tremors followed by one principal shock, which lasted 2 seconds. Direction S. W. to N. E. Distinctly felt. He ran out of doors. No sound or other effects.

Manand Choudhuri, Deputy Magistrate and Deputy Collector at Jessore town: Time between 10 and 11 A.M. One prominent shock. Distinctly felt. No sound or other effects.

It is probable that a slightly greater intensity is indicated by the former of these records, inasmuch as preliminary tremors were noticed in addition to a chief shock and from the fact that the shock was sufficiently alarming to make the observer leave the house. Hence we may perhaps draw the dividing line between intensity VI—VII and IV—V somewhere between Bangaon and Jessore.

(8) Khulna district.

Khulna district lies to the east of Calcutta. Five forms were sent in. In all of them the intensity was described as "slight," and as there were no additional facts stated to warrant a contrary belief, it is reasonable to conclude that the area lay outside that of intensity VI—VII. The results are given in tabular form.

Locality and observer.	Number of shocks, direction and duration.	Sound.	Other effects.
Khulna town—			
N. R. Misra .	One . . .	..	...
Basirhat—			
Mahommed Shamsul Soha, Sub-Divisional Officer.	One . . .	...	...

Locality and observer.	Number of shocks, direction and duration.	Sound.	Other effects.
Senhati—			
Sarada Charan Mukerjee.	Two. N. E.—S. W.	...	...
Shatkhira—			
Hari Nath Mozumder, B.A., Pleader.	Two or three within a second. N.—S.	None	...
Raruli—			
Nalinikanta Raychaudhuri.	One	...	...

The above completes the inner circle of districts surrounding Calcutta as a centre.

(9) Faridpur district.

Faridpur district lies north-east of Jessore, and belongs to an outer circle of districts which will now be described. Only one form has been received as follows:—

Mohendra Nath Bose of Gopalganj: Time 11-0. One shock. Direction N. S. Distinctly felt by 200 persons at a meeting on the first floor of a two-storeyed house. The people felt dizzy. No damage to buildings.

An intensity of at least IV to V is indicated by this form, but its being unaccompanied by any other forms from surrounding towns makes one hesitate to ascribe to it a higher intensity number.

(10) Pabna district.
(11) Rajshahi district.

From Pabna and Rajshahi districts, lying respectively to the north-east and north of Nadia district, only one form from each has been received, which are as follows:—

Ganga Charan Banerjee, Government Telegraph Office, Serajganj: One shock very slightly felt.

Haran Chandra Banerjee, District Engineer, Rampur-Baulia: Time 10-25 (standard time) = 10-48-21 Calcutta time. One slight shock. Direction E.—W. Rumbling sound before.

The first of these forms indicates, alike in its own matter and as standing alone, that it lies on the extreme limit of sensibility. We must therefore give it the lowest value of the intensity scale, namely, II to III. The second one from Rampur-Baulia indicates a slightly higher intensity and must come close to the dividing line between intensities II—III and IV—V.

(12) Murshidabad district.

Murshidabad district lies north-north-west of Nadia, but stretches further south than Rampur-Baulia just mentioned. Four forms have been received which are tabulated below.

Locality and observer.	Number of shocks, direction and duration.	Sound.	Other effects.
Berhampore—			
Upendra Nath De, Meteorological Observer.	Four or five prominent shocks, at intervals of about 2 seconds. S. W.—N. E. Tremulous vibrations after for 1½ seconds.	None . .	Furniture and articles in room were displaced. Earthenware pot overturned to east.
Shahanagore—			
Ras Behari Dutt, Inspector of Police.	One prominent shock E.—W.	None . .	None.
Ichaganj—			
Rojani Bhoshan Dhar.	A tremulous vibration followed by two shocks. S. W.—N. E. 4 seconds' duration.	Rumbling sound preceded the shock by 1 second.	Basket hanging on nail fell. Slight crack in doorway arch of his house.
Batia—			
Babu Madhushudan Sing, B.A., Head Master at Higher English School.	Two principal shocks W.—E.	None . .	None.

The times given are sufficiently near to 11 A.M. to make it certain that we are dealing with the same earthquake, but it is quite clear that the intensities are somewhat greater than would be expected in comparison with its neighbour districts. It is clear that in the southern parts of this district the intensity figure reached VI to VII.

(13) Birbhum district.

Birbhum district lies to the north of Bardwan. Two forms only have reached me, which are as follows:—

Syed Ezhar Hassan, Sub-Deputy Magistrate of Rampur Hat: Time 10-55 A.M. (standard time) = 11-18·21 Calcutta time. A to-and-fro movement from north to south. Slightly but distinctly felt. No sound or other effects.

Benode Behari Sanyal, Overseer of Suri: About 10-45 (standard time) = 11-8·21 Calcutta time. Three shocks E.—W. No sound or other effects.

We may estimate the intensity here as IV to V.

(14) Tippera district.

Only one other district is represented by one form, namely, Tippera, which lies some way to the east beyond Faridpur. It is as follows:—

Mr. H. M. Parish, Superintendent of Police, Comilla: Time 10-40 A.M. (standard time) = 11-3·21 Calcutta time. One slow rocking motion lasting about 4 seconds. Direction N—S. No sound or other effects.

Estimate of intensity II—III.

General remarks: No data as to rate of transmission, acceleration, etc.

Over such relatively short distances as are involved in this earthquake, and with such imperfections (as we must admit) in the time records, it is of course hopeless to think of drawing any inferences as to the velocity of transmission of the wave. The absence of the necessary data also precludes any inferences as to the acceleration or other elements of the wave motion.

Earthquake sound.

The earthquake sound was of the usual character. From the low pitch of its note, somewhere near the limit of audibility, it was natural to expect that at no single locality would there be unanimous testimony as to its having been heard. Such unanimity is seldom found away from the epicentral area of a very great earthquake. In the case of this earthquake the positive statements of those who heard a sound are never more than about equal in number to the statements of those who

either did not hear it or did not mention it at all. In the Calcutta, Hugli, and Nadia districts the "ayes" and "noes" are about equal. If we club together the reports from Calcutta, Midnapore, Howrah, Hugli, Bardwan, Nadia, Jessore, and Khulna, which together form the central group of districts, we shall find the proportion, ayes to noes, = 14 to 22, which is a little more than ½. On the other hand, clubbing together the outer circle of districts, namely, Faridpur, Pabna, Rajshahi, Murshidabad, Birbhum, and Tippera, the proportion is, ayes to noes, = 2 to 7, which is a little more than ¼. This result shows that the percentage of those that heard the sound in the outer districts is smaller than that of those in the inner districts, and indicates a proportionate diminution in the sound with the distance from the more central area.

Nature of the centrum.

It seems fairly well established from the distribution of the intensities, as indicated on the map by the isoseismal lines, that the innermost area circumscribed by the isoseismal VI—VII is elongated in a N.—S. line, and that the centrum lies somewhere beneath that central elongated area which coincides roughly with the course of the Bhagirathi river down to its junction with the Hugli river. All further details are, however, impossible. A consideration of the directions of shock, as given by the observers in the forms, shows the usual want of congruity. If, however, we tabulate the results for the whole area, we find one striking peculiarity: whilst there are about an equal number of recorded directions of shock lying N.—S., E.—W., and N. E.—S. W., there is only one recorded direction N. W.—S. E. and one W. N. W—E.S.E. Allowing for imperfectly received impressions and for inaccurate notions as to the true points of the compass, I am unable to suggest an explanation of the above peculiarity in a region that covers the whole of the "felt" area.

Number of principal shocks.

There is a great want of uniformity in the records as to the number of the principal and prominent shocks felt. Whilst in Calcutta, Midnapore, Howrah, Nadia, and Murshidabad the number is generally two or more; in Bardwan, Jessore, Khulna, Faridpur, Pabna, Rajshahi, and Tippera the number is generally one. In the district of Hugli eleven observers recorded one shock, and three recorded two shocks. I cannot detect any law underlying this distribution of the

recorded number of shocks, except that in the outer districts where the earthquake was of course weaker, and so less easily appreciable, only a single shock has been recorded.

Cause of the earthquake.

As to the cause of the earthquake, when it is remembered that over the whole area a great thickness of the alluvial soil of the delta entirely conceals the arrangement of the solid rocks below, it will be readily understood that, although many lines of weakness may be supposed to exist beneath the epicentral area, it is impossible to point to any that are definitely known.

Other earthquakes on 29th September.

There can be no doubt that the descriptions given above of the earthquake phenomena occurring on the 29th September, by reason of their connectedness in space and time, form the records of but a single earthquake. Although the times differ considerably in some places, such differences are not more than may be expected from the imperfect system of time recording in vogue in India. But in other parts of North-East India the forms sent in have furnished descriptions of shocks occurring on the same date (namely, 29th September), but at such times that they obviously cannot be classed with the 11 o'clock earthquake.

Assam.

At 4-45 A.M. on that date Mr. E. Bridge, of Kopati Tea Estate, Tezpur, Darrang district, described a shock of considerable severity, and which in his opinion was the worst shock since 1897. There were two preliminary shocks, followed by the main shock and then tremulous vibrations for two seconds. Directions N.—S. A wine-glass was thrown down to the south. Clocks stopped. Plaster on "ekra" built walls fell, and there was a heavy rumbling sound. This shock appears to have been quite local, and to have been connected with the aftershocks of the 1897 quake.

North Bengal.

On the same date also in the northern parts of Bengal forms have come in from Darjiling, Kurseong, and Siliguri (Darjiling district), Dinapur (Patna district), Jamtara (Sonthal Parganas), Laheria Serai (Darbhanga), and Jenida (Jessore district) recording an earthquake or earthquakes at various times between 7 A.M. and 9 A.M. The time 7-5 as recorded at Kurseong and Dinapur, and 7-15 at Laheria Serai being the more

precise. This shock or series of shocks was slight at the two latter places, but at Siliguri, doors, windows, punkahs, and the whole building seem to have moved, and the shock must have reached an intensity of about VI.

The few forms received are insufficient to make any more precise statement regarding the shock or shocks.

In addition to these, on the same day but in the evening at about 8 P.M. shocks were recorded from Monghir, Gopalganj (Faridpur district), and Silchar (Cachar district). There was also one at about midnight (which midnight not stated) at Sibsagar.

Earthquake of 6th December 1906.

General.

The second of the Calcutta earthquakes of 1906 was of less importance. It took place about 6-8 P.M. Calcutta time on the 6th December. No earthquake forms were issued in respect of this earthquake, so that it is impossible to produce a map defining the seismic area. It is probable, however, that though with less energy, it had an origin which may be located somewhere near that of 11 A.M. on the 29th September.

It was a sharp shock, felt by nearly everyone indoors at the time. The upper storeys of large buildings swayed. People prepared to rush out of doors. Some asleep at the time were awakened. There were cracks produced in the plaster of many houses in Calcutta.

Effects in Calcutta.

Mr. E. Vredenburg, of the Geological Survey of India, who was living at the Grand Hotel, Chowringhee Road, in a third-storey room, described it as a long swing N.—S. dying down and then followed by an E.—W. swing not so intense. Its duration was about 1 minute. Crows rose from the trees and cawed. No objects were overthrown. Mr. K. A. K. Hallowes, also of the Geological Survey, described hanging lamps swinging N.—S. first and then E.—W. I myself was walking at the time and did not notice it. No sound was recorded.

Indian Museum.

Mr. I. H. Burkill, of the Industrial Section of the Indian Museum, again kindly supplied us with a few notes made by Mr. Vieux, which ran as follows :—"No damage occurred in any of the galleries by this earthquake. Some candles, however, in Messrs. Shaw, Wallace & Co.'s case fell towards the west, and, judging from the position in which I saw them lying on

the following morning, I think that the shock travelled along the length of the building, as was the case on the 29th September."

A few people think there were two shocks with 15 minutes' interval, but there seems to be some doubt about this.

In the terms of the Rossi-Forel scale it would seem that the intensity was about equal to V or VI.

Bardwan.

Mr. H. F. Samman, I.C.S., Collector of Bardwan, reported in a letter that he felt a single shock of earthquake at 6-10 P.M. (local time). The wave appeared to travel from west to east. Duration about 2 seconds.

Seismographs.

It was not felt at Simla by the long-distance Omori seismograph. It was, however, registered on the Milne seismograph at Alipore, Calcutta,[1] the time given being (commencement of tremors 12 hours 14·8 minutes G. M. T.) which is equivalent to 18 hours 8 minutes 9 seconds Calcutta time. Duration 36 seconds. Maximum displacement on the trace measured from the base line 6 mm. A thickening of the trace was also recorded on the same instrument 5 minutes 30 seconds before.

[1] Monthly Weather Report, December 1906.

MISCELLANEOUS NOTES.

Note on Barytes occurring at Narravada, Nellore District.

DURING the field-season 1906-07 I visited some shallow workings on some veins of barytes in the neighbourhood of Narravada (Lat. 14° 54′; Long. 79° 29′). The veins were being opened up on the advice of Mr. V. S. Sambasiva Iyer of the Mysore Geological Department.

The barytes occurs in two low hills, about 3 miles east of the village of Narravada, as irregular veins in a band of fine-grained mica-schist. It is seen in outcrop on the top and northern slope of a low hill, and is again seen on the slopes of a second hill to the south-east.

The veins usually follow the strike of the band in which they occur, but in some cases cut obliquely across and appear gradually to pass into the mica-schist. The band strikes N. 45° W. and dips 40° S. W.

The barytes is quite opaque, and of a greyish colour, but some pieces from the lower slopes of the hill have a dull milky colour. It has a specific gravity of 4·46, but is often largely mixed with the mica-schist, which reduces the specific gravity of the samples.

The country rock is a dark-grey, fine-grained mica-schist. Specimens taken about 10 feet from any visible barytes veins, when examined under the microscope, are found by analysis to contain a considerable quantity of barytes. The miscroscopic examination shows the rock to be made up of quartz, biotite, barytes, magnetite, and a little calcite. The barytes occurs as small grains scattered throughout the rock.

[H. CECIL JONES.]

Memorandum on the Tourmaline Mines of Maingnin. By E. C. S. George, I.C.S., Deputy Commissioner, Ruby Mines District.

The mines at present worked are situated all round the small Palaung hamlet of Sanka, about a mile east of Maingnin, which is said to be six *daings* (18 miles) to the north-east of Momeit in the directions of the high hill Loi Tôk from which flows the Namlang, an affluent of the Nammeit, which marks the boundary between the Kodaung and Momeit Townships.

Maingnin itself is a long straggling village of 93 houses at the head of a long narrow valley terraced with lateral offshoots for over a mile for paddy cultivation. The mines are situated on the top and sides of the ridge hemming in Maingnin from the east. The original discoverers and workers

of these mines were Chinese, who, according to local tradition, worked here some 150 to 200 years ago, but whose occupation appears to have been discouraged when the then *Sawbwa* of Momeit, having arranged to obtain a Chinese princess for his bride, instead of getting the youngest and most beautiful of a bunch of three offered for selection, found, when the closed litter carrying the prospective bride arrived in his territory, that the eldest had been palmed off on him. Tradition says that she was so ugly that when the *Sawbwa's* Ministers sent to meet and welcome her *en route* insisted on opening the litter, they were so nauseated that they could not enjoy their meals, an event commemorated to this day in the name of the spot Nan Kai-San [the stream where the fowl's flesh (they had chicken for dinner) tasted insipid].

However, after having extensively worked the mines on the hillside at Hpaibaing or Milaung-gôn, about a mile from Sanka (still bearing traces of their channels), the Chinese disappeared, and apparently the place was left deserted until about the year 1230 (1867-68) when the Kachin *Taung-gyop* of Loiya, the most powerful Kachin of these parts, collected a large number of Kachins and re-started the mines. A short trial was enough to sicken the Kachins with the results and though they did, from time to time, spasmodically dig, no serious attempt was made to revive the industry, chiefly because the Momeit *Sawbwa's* law did not run here and not a Shan or Burman dared show his nose out of the plains.

Later, a Shan adventurer from Namkam known as Kyi San Pi in 1244-45 (1882-83) collected some fifty followers, overawed the local Kachins and worked for one season. This was about the time that Kan Hlaing was making things uncomfortable for the then *Sawbwa* of Momeit Kan U, who called Kyi San Pi and his band to his aid. Kyi San Pi attacked Kan Hlaing's adherents at Sagadaung but was killed. Thereafter in 1248 (1885-86) Pu Seinda, still living at Maingnin, a Palaung from Manhè, came with four companions and re-established the village of Maingnin, in the valley below the traditionary Chinese village Wen-Chow, since which time the industry has been systematically conducted to date, though with considerable periods of depression, the village having at times dwindled to six or seven huts. Its present size is due to the discoveries of last year, 1905, having had a stimulating effect. Seinda to begin with required and obtained no permission from the Momeit *Sawbwa*, but he had to pay about the equivalent of Rs. 1,500 to the Paw Maing Makala of Lwèya and the *Taung-gyop* chiefs of the Kachin villages who claimed to control the tract, in order to obtain protection from raids.

Seinda and his comrades spent the first year in the construction of a long water channel from Lai Manhè on the west to work the mines on the *Myaw* system used by the Chinese, the Kachins having contented themselves with

digging shallow holes and therefore obtaining only poor specimens of the gem. Seeing his success the Kachins turned up next year and the mines attracted the attention of the *Sawbwa* Kan U, with the result that in 1250 (1887-88) with the breaking down of the power of the Kachins, the *Sawbwa* instructed Seinda to collect a tax of 5 per cent. from the buyer and 2½ per cent. from the seller on all sales of stones extracted. Seinda did this and says that that year he paid in 800 rupees to the *Sawbwa*, on which he got no commission. This was further enhanced next year, when the Nyaungywe *Sawbwa* ruled Momeit, to a cess of 5 per cent. each from the seller and from the buyer. Seinda only managed to pay in 25 or 30 rupees and in 1252 (1889-90), a revised system was introduced, when each man at work in a *Myaw* was made to pay two rupees a month and each *Twinlôn* worker one rupee. But Seinda was no longer allowed to collect and a *Than-daw-zin* from Momeit, first U Peik, and then U San Dun, was sent to collect. It is not known locally how these were remunerated nor what was the total of collections.

In 1255 (1892-93), Mr. Daniell arranged to farm out to Seinda the collections at the above rates for 1,200 rupees a year. Seinda says he lost over this, but the year following, when the collection of the revenue was put up to auction, he bid up to 2,850 rupees for it. His explanation is that he wanted to retain the position of "boss" of this place, which was founded by him, and that the effort to do so has ruined him. He certainly is not very well off at present, for he cannot raise enough spare cash to wall his house in properly. It looks more like a *zayat*. However, he still manages to keep his *Myaw* at work in the rains. In 1257 (1894-95) in default of any one else, the collection was again offered to him for 2,850 rupees, and he foolishly took it at that figure, but the mines failed to yield. Maingnin was practically deserted, and after Seinda had paid up 2,000 rupees, he was let off the balance as irrecoverable. Then in 1258 the Momeit stone tract was notified. Originally the amount to be paid per man working was fixed at Rs. 10 per month, but when Mr. Fleming visited the Maingnin Mines, it was pointed out that this was too much and the rate was reduced to Rs. 2 per each man at work per month, and this rate has obtained ever since.

The amounts recovered under the head "Tourmaline licenses" appear to have been as follows:—

Year from 1st January to 31st December.	Amount. Rs.	
1899	190	for ten months.
1900	1,516	
1901	948	
1902	328	
1903	2,935	
1904	3,090	
1905	2,010	

Tourmaline is found in separate crystals in the interstices of a hard granitic looking rock. The surface soil is of a dark red colour, and at a depth of 6 to 10 feet about, this is found mixed with a whitish friable rock in which isolated small bits of tourmaline are from time to time found.

As a consequence men with no means find it occasionally profitable, when they have leisure, to dig down 8 or 10 feet on the off-chance of finding some not very valuable bits.

(*a*) This system is called "Kathè taik" or "Kathè system" after the idea of the original ruby diggings at Kathè. It is regarded much in the same light as the *Kanese* method at Mogôk and no tax appears to have been hitherto collected on workers by this system though there appears to be no valid authority for the omission to tax them.

(*b*) The next method is the ordinary *Twinlôn* method of sinking a vertical shaft about 4 or 5 feet square. By custom the owner of the shaft is entitled to extend his workings underground anywhere to a radius of five fathoms from the centre of the shaft.

In this way the vein, or *Kyaw*, is reached, in which the tourmaline is found embedded, in irregular crystals for the most part hexagonal with a flattish base, usually of a dark colour, varying from brown to black; while the upper portion, which is of the light transparent pink, which is the most highly prized colour, terminates usually in the intersection of three planes, the extreme apex of which is usually found flattened, making a small triangle. In the most valuable variety, which is found in a matrix of white, the area of this triangle at the apex is so extensive that it covers nearly the whole surface of the upper end of the crystal, so that it appears to have been sliced off. For some reason it appears, from what the local people say, that crystals with this flattened top are practically always without much of the lower badly discoloured portion, and present an even transparent colour.

The "vein" is formed by a vein of white, hard, granitic rock, in the interstices of which the tourmaline is found, at times adhering loosely to the rock, at others lying separate in the loose yellowish earth that is found with the granite. When a vein is once found it is followed up as far as possible subject to the five-fathom limit alluded to above. What, however, makes the mining so exciting and at the same time keeps the industry fluctuating, is that the tourmaline crystals are only found intermittently in the vein. One may get several in the length of one yard, and then they will unaccountably cease. Directly one man strikes a vein yielding crystals everyone who can commences digging along the lie of the vein, but it is all a toss up as to whether, when the vein is reached, there will be tourmaline therein. Adjoining *twinlôns* give absolutely different results,

and it is calculated that at least two-thirds of the shafts sunk yield nothing at all, while only an occasional one is at all rich. Of the 62 *twinlôns* at my visit only three were yielding, and of these only one had traces of the best quality stone. The "veins" are fairly deep down, none having ever been reached at a lesser depth than nine fathoms, while an ordinary depth is 40 or 50 cubits. When the "vein" takes a downward direction it is followed as far as possible, but that is rarely over about 60 cubits, for at that depth the foulness of the air puts the lamps out. Work in the *twinlôns* ceases in the rains, from *Kasôn* to *Thadingyut*, because of the difficulty of working in dim light and of the liability to flooding of the pits. Ordinarily the condition of the industry is depressed and except for Kathè workings, which have hitherto escaped taxation, nothing much is done unless and until some one strikes a rich vein, when there is a rush to the spot.

The vein is said rarely if ever to show an outcrop, and it is a matter of pure speculation where to dig. As the whole place is covered with jungle, prospecting any way would be laborious. Since the industry was re-started by Seinda, who has not been successful with his *Myaws*, there have been three finds, each causing a rush.

The first was some seven years ago at Hpai Baing (Milaungg̀ôn), about a mile to the south of the present place, and near where the Chinese had worked formerly.

The next was a year or two later at Htaukat between Milaungg̀ôn and Sanka. Then there were three or four lean years, and then early in 1905 one Konhkan struck a vein near Sanka village, which has attracted the present growth of population to Maingnin, but, as explained above, though the area within 100 yards of Konhkan's original shaft is honeycombed with pits, only three are yielding and Konhkan's *twin* has ceased to yield. It should be noted that at every *twinlôn* is put up a small "*Katsin*," fashioned after the pattern of a house, with open sides, and gay with flags to the "Maingnin" Shin Ma, the unfortunate ugly Chinese Princess noted above, whose spirit now rules the place. She is placated with daily offerings while work is going on.

All the material dug out from inside the *twinlôn* is pulled up to the surface in small buckets, all worked by enormously long pivoted bamboos worked with a counterpoise, and the tourmaline is sorted out by hand, the granitic fragments being piled in a wall round the mouth of the shaft. The *Twin Gaung* or owner employs, as a rule, three men per shaft to do all the work of digging. He pays the license fees and all expenses,

except hutting and clothing. The cost of food of a cooly per month is estimated at Rs. 10, rice being sometimes as much as Rs. 7 a basket. All tourmaline found is sorted into three sorts:

(1) *Ahtet yay*, the best light pink coloured, of which the sort most estimated is—

(*a*) *Hteik Ti* or flattened at the top as noted above.

(*b*) *Bè Yan* is the usual kind with a conical top formed by the meeting of three planes.

(2) *Ahka* (waist or side).—This is of a darker colour generally, and has the lower portion of the crystals' length discoloured brown to black.

(3) *Sinsi* or *Amyi* (tail) which includes all fragmentary crystals of whatever colour or water which are imperfect, or of a small size less than about an inch. The purchaser bids for only the two better kinds and the "*sinsi*" is thrown in for nothing. The stones are sold by weight, *Ahtet yay* fetching from Rs. 1,200 to Rs. 1,500 per viss, while *Ahka* fetches about Rs. 500 for that quantity.

It is said to be impossible to give any average time as to how long it takes to collect a viss, as the finding of the gem is so uncertain. Anyway, whatever the stones out of each *twinlôn* fetch in the aggregate, is divided in half between the *Twin Gaung* on the one hand and the coolies jointly on the other.

All purchases made locally are made by brokers, usually Shans or Shan Burmans, who reside at Momeit or on the spot. They in turn re-sell at Mandalay to the Chinese who make a market for the gem. The brokers are said, owing to the restricted market, by no means always to make on the transaction. Apparently the Chinese merchants do not themselves come up to buy direct at the locality, as they do at the Jade Mines.

(*c*) The last system is the *Myaw*, hydraulic washing away of the hillside till a vein is met with. There are only two *Myaws*, one owned by Seinda, noted above, and the other by one Maung Peik, to whom Seinda sold the lower of two water channels made by him, for Rs. 175. Naturally this system cannot extend much, as Seinda had to bring his water for miles from Manhè hill, to the west of the head of the Maingnin valley while operations can only be conducted in the rains when there is water. Nothing is going on at present. The *Myaw Gaungs* are said to pay Rs. 2 per month for each cooly employed by them.

No one could give me any approximate estimate of the total outturn annually.

Nummulites Vredenburgi, Prever, nom. mut.

In Vol. XXXIV of these *Records* (1906, pp. 79-95, Pl. VIII), I described what I thought to be a new species of nummulite, from Kachh, as *Nummulites Douvillei*, unaware that this name had already been bestowed in 1902 by Dr. Prever on a nummulite from the neighbourhood of Potenza in the southern Apennine. (Le nummuliti della Forca di Presta nell'Appennino Centrale e dei dintorni di Potenza nell'Appennino Meridionale, *Mem. Soc. Pal. Suisse*, Vol. XXIX.) There is no copy of the above-mentioned valuable Monograph in the Library of the Geological Survey and it is Dr. Prever himself who kindly informed me of my having duplicated his previously defined name, doing me, at the same time, the great honour, which I gratefully accept, of proposing to name the Kachh nummulite *Nummulites Vredenburgi*, either as a marked variety of *Nummulites parva*, another species described by Dr. Prever in the above-mentioned monograph, or, if sufficiently distinct, as an independent species. Having received, by last mail, a copy of Dr. Prever's Monograph, I have been able to compare my specimens with the descriptions and figures of *N. parva*, (*loc. cit.* p. 68, Pl. VII, figs. 1, 2), and they appear to me specifically distinct; this, however, cannot be definitely settled without a direct comparison of the specimens.

[E. W. VREDENBURG.]

Additional note concerning a previous notice on "The Ammonites of the Bagh Beds," pages 109 to 125 of present volume.

When writing the above-mentioned notice, I omitted to compare with the Indian specimens, certain forms from the cretaceous rocks of North America, described in the late Professor Hyatt's great monograph on the cretaceous pseudoceratites. (*Mon. U. S. G. S.*, XLIV, 1903.) On referring to this work, I find that the two species for which I ventured to propose a new genus "*Namadoceras*" probably fit into Hyatt's genus *Cœlopoceras*, though none of the American species figured show such a marked bipartite subdivision of the external saddle as *Ammonites Bosei* of the Bagh beds, while the auxiliary series, in the American forms, is subdivided into more numerous inflections, especially when compared with *A. Scindiæ* which has only one auxiliary saddle. Amongst the forms which I had mentioned as closely related to the Bagh ammonites, I notice that *A. Requieni* is actually regarded by Hyatt as a *Cœlopoceras*, and *A. Gevrilianus* as a member of a closely related genus, *Platylenticeras*. The American species of *Cœlopoceras* are from the Colorado-group, and are regarded as Turonian, which is also the

geological age of *Cœlopoceras Requieni*. If the two Bagh ammonites are also referred to *Cœlopoceras*, the range of the genus must be extended downwards into the Cenomanian.

Owing to the insufficient state of preservation of the Bagh specimens, the existence of the characteristic hollow keel mentioned by Hyatt cannot be verified.

Another genus which seems closely related is *Hoplitoides*, von Koenen, from the Cameroon country in West Africa. Unfortunately, von Koenen's[1] and Solger's[2] important memoirs on the cretaceous of Cameroon are neither of them available in Calcutta. I gather from Mr. Sayn's account in the *Revue critique de Paléozoologie* (1906, pp. 47-50), that Dr. Solger regards the *Hoplitoides*-bearing beds of Cameroon as Lower Turonian, their base perhaps reaching into the Cenomanian.

E. W. VREDENBURG.

[1] *Abhandl. der Kön. Ges. d. Wiss. zu Goettingen, math-phys. Kl.*, n F., Vol. I.

[2] *Beitr. z Geol. v. Kamerun*, 1904.

RECORDS

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PSEUDO-FUCOIDS FROM THE PAB SANDSTONES AT FORT MUNRO, AND FROM THE VINDHYAN SERIES. BY ERNEST W. VREDENBURG, A.R.C.S., A.R.S.M., F.G.S., *Geological Survey of India.* (With Plates 31 to 34.)

IT is always a most gratifying duty for the Geological Survey to record the assistance rendered to the Department by non-official geologists. A number of interesting specimens have lately been forwarded to the Geological Museum from Fort Munro, a hill-station situated in the Suleiman range. The senders of these interesting collections are the Reverend Mr. Lee-Mayer, Mr. H. J. Maynard, I.C.S., Commissioner of Multan, Major F. W. Pirrie, Deputy Superintendent of the Survey of India, and Captain F. C. Nicolas, Assistant Commissioner, Border Military Police of Dera Ghazi Khan.

The Suleiman range is the outermost ridge of the hilly region of eastern Baluchistan, itself a segment of the great Iranian "arc." At Fort Munro, the structure of the Suleiman range is that of an anticlinal arch leaning outwards, that is, to the east, in accordance with the unsymmetrical disposition characteristic of mountain folds: the eastern limb of the anticline dips at much steeper angles than the western one.

The road from Dera Ghazi Khan to Fort Munro, after leaving the richly cultivated belt with shady avenues of magnificent trees, extending for several miles west of the Indus, enters a barren plain of the type which is everywhere familiar throughout the north-western frontier of India.

Shortly before reaching the foot of the Suleiman range the

road skirts the northern extremity of an elongated low anticline of Siwalik sandstones, forming an adventitious fold in front of the main border of the range. The road next passes south of the picturesque town of Sakhi Sarwar, clustering round a holy shrine held in great veneration by the followers of both the Koran and the Vedas, and standing on the lower slopes of a spur of Siwaliks forming the southern extremity of another adventitious anticlinal roll of much greater importance than the one just mentioned as occurring south of the road.

There is a staging bungalow at this point, about four miles beyond which commences the ascent up the Suleiman range proper. The road winds through one of the most important passes across the Suleiman range, and, at all times of the year, but especially in spring and autumn, it is thronged with the most delightfully picturesque gaily clad people, either on their way down to the Punjab plains to avoid the severe winter of their native mountains, or on their homeward journey with the return of the warm weather.

It should be noticed that until within some three miles (as the crow flies) from Fort Munro, the road, while it constantly ascends in altitude, follows a constantly descending geological section. This is because it travels towards the axis of an anticline across dips which are much steeper than the general slope of the hill-sides. The outermost slopes consist of the Siwalik formation, largely built of buff-coloured sandstones, often conglomeratic, especially in their uppermost layers, while towards their base they frequently assume red tints and are associated with bright-coloured clays. I am not certain whether, in addition to the Lower Siwaliks, these lowermost beds do not contain representatives of the Nari or Gaj formations of Sind (Murree beds of the Punjab), which when unfossiliferous are easily mistaken for the Lower Siwaliks. I drove across the outcrop in April 1906, but could not afford sufficient time to ascertain this point. Oligocene or lower miocene beds are known at a short distance both north and south of Fort Munro.[1]

[1] The road to Fort Munro follows the gorge of the Rahki river. According to W. T. Blanford, who examined the Suleiman range cursorily in the year 1882, the gorge of the Siri river, some four or five miles further north, cuts through a conspicuous exposure of oligocene beds underlying the bottom conglomerate of the Lower Siwaliks. (Mem., G. S. I., Vol. XX, p. 224.)

The base of the variegated strata, whether it be Middle or Upper Tertiary, rests directly upon eocene nummulitic beds of Lower Lutetian age, corresponding with the Laki formation of Sind and Baluchistan (the coal-bearing group in Baluchistan and the Punjab). The Upper Lutetian limestones known elsewhere as the Khirthar group are absent from this part of the Suleiman range. The uppermost stratum of the eocene beds is a white limestone of small thickness crowded with specimens of *Orthophragmina.* It rests upon a thick series of grey shales corresponding with Mr. Oldham's Ghazij group of the Harnai valley, resting in their turn upon a dark nummulitic limestone crowded with alveolinæ, representing the subdivision distinguished by Griesbach in Baluchistan under the name of "Alveolina limestone," and also occurring in Sind where it constitutes the Laki range.[1] In addition to alveolinæ, this limestone contains nummulites, which I have identified as *Nummulites atacicus, N. irregularis,* and *Assilina granulosa,* all of which elsewhere characterise the Laki formation. Weathered casts of a large *Cerithium,* of a *Rostellaria* like shell, and of a large *Lucina,* and a specimen of a big *Conoclypeus,* have been collected from the same rock, on the western side of the anticline, by Mr. Maynard and Captain Nicolas. This limestone exhibits the brecciated structure frequently observed in the Alveolina limestone (and sometimes also in the Lower Khirthar limestone) in Baluchistan, which I regard as a contemporaneous structure due to wave or current action, previous to the definitive consolidation of the rock. (*Rec., G. S. I.,* XXXIV, p. 178.)

The dark-grey Alveolina limestone rests on an almost black limestone of small thickness, at the base of which there is a bed of laterite. These lateritic layers, even when of insignificant thickness, are of great assistance in unravelling the stratigraphy of Baluchistan, as they reveal the existence of hidden unconformities or gaps in the sedimentary sequence, otherwise unrecognisable owing to parallelism

[1] In his account of Baluchistan, W. T. Blanford endeavoured to disprove the existence of the Alveolina limestone discovered by Griesbach. (*Mem., G. S. I.,* XX, pp. 115, 119-122.) Subsequent researches have established the correctness of Griesbach's views, not only in Baluchistan, but even in the type area of Blanford's previous work in Sind, where the Alveolina limestone, developed on a grand scale in the Laki range, had been mistaken for the newer Khirthar limestone. (*Centralblatt für Mineralogie, Geologie und Palæontologie,* 1903, p. 521, 1905, pp. 135, 170; *Rec., G. S. I.,* XXXIV, pp. 79-95, 171, 198.)

of stratification between formations vastly differing in age. The failure to recognise these gaps has greatly retarded the completion of our survey of Baluchistan and has even led to erroneous conclusions, such as the supposed existence of a continuous passage between Cretaceous and Tertiary, which can now be shown to be no more existent in India than in Europe. (See *Rec., G. S. I.*, XXXIV, pp. 86, 173, 174, 182, XXXV, pp. 117-118.)

The accurate stratigraphical details supplied by Mr. Maynard in illustration of his collections, indicate that some of the fossils lately forwarded to Calcutta belong to this lateritic layer, constituting locally the base of the Tertiary system. Mr. Maynard's specimens from this horizon are probably from the western limb of the Fort Munro anticline. Where I crossed the outcrop of the lateritic layer along the eastern limb, I found it unfossiliferous. Mr. Maynard's specimens were collected "on the road to the Dhobi Ghat, where it crosses the bottom of the valley." They include a small chambered nucleus of a *Nautilus,* some simple corals, and a fossil fruit, in all of which the original substance is entirely replaced by hydrous iron oxide. Pl. 31, fig. 1, 1*a*, shows the outer aspect and a section of the fruit. I have shown this fossil to Mr. I. H. Burkill, Superintendent of the Industrial Section, Indian Museum, who has very kindly given me the following particulars: "It is a trilocular fruit with more than one ovule in a loculus; placentation apparently axile; seeds suspended; the unpaired cavity is empty, the paired cavities carrying the seeds present, but the unpaired cavity is in no way aborted, but fully as large as the others. The fruit has the size and appearance of that of *Iris*, but there is no reason for assuming it to be an *Iris*: indeed the ovary walls thickened laterally, and the slight compression of the fruit, which suggests that it belonged to a cone, are quite foreign to the Iridiaceæ. The presence of more than one ovule in a loculus renders the fruit different from that of a palm, which the thick ovary walls would otherwise suggest."

I have not seen any description of a fossil fruit identical with this specimen; it does not help therefore the determination of the age of the rock. Of the other fossils discovered by Mr. Maynard in the same layer, the corals belong to a species of *Trochosmilia* which I have not identified with any described form, and the *Nautilus* is too fragmentary for determination. Occurring as they do in the laterite, which originated from the atmospheric alteration

of the surface of the cretaceous series, left exposed to the air by the retiring waters of the cretaceous ocean, they probably represent the organic remains preserved in the uppermost cretaceous bed of this locality. In Jhalawan, I have on several occasions found numerous fossils from the *Cardita Beaumonti* beds (uppermost cretaceous), entirely pseudomorphed by iron oxide at the junction of these beds with the overlying eocene. It is nevertheless possible that the same mode of fossilisation might affect the first organic remains, laid down on the lateritic surface, on the return of the eocene ocean: in Sind, where a laterite band represents a stratigraphical gap between the Ranikot and the overlying Laki series, I have observed nummulites and echinoids of Laki age transformed into iron oxide where the base of the formation rests upon the laterite. Nevertheless, the conditions at Fort Munro are so similar to those observed in Jhalawan that it is more probable that the remarkable fossils collected by Mr. Maynard belong to the stratum below the unconformity, and are therefore uppermost cretaceous. They are sufficiently interesting to justify further investigation.

The whole of the eocene outcrop is excessively contracted along the eastern limb of the anticline, owing to the high angle of dip; but west of the outcrop of the underlying cretaceous, the Alveolina limestone spreads horizontally over considerable areas along the flat summit of the arch, constituting the plateau upon which stands Fort Munro. Further to the westward, judging from an unpublished survey commenced by my colleague, Mr. F. H. Smith, it continues to a considerable distance in the shape of a relatively gentle dip slope.

By comparison with similar sections studied in other areas, and from palæontological evidence, it can be shown that the beds immediately underlying the laterite are of cretaceous age (Danian or uppermost Maestrichtian). Far from there being a gradual passage from cretaceous to tertiary as has invariably been assumed in previously published descriptions of the Suleiman range[1], it is therefore evident

[1] W. T. Blanford, Sind and Punjab Frontier, *Mem.*, *G. S. I.*, Vol. XX, p. 108 (1883). In this work Dr. Blanford regarded the whole of the *Cardita Beaumonti* beds as eocene, and his classification was more or less followed by Griesbach (Geology of the Takht-i-Suleiman, *Rec.*, *G. S. I.*, XVII, pp. 175-190, 1884), and by LaTouche (Geology of the Sherani Hills, *Rec.*, *G. S. I.*, XXVI, pp. 77-96, 1893), who nevertheless mentions that R. D. Oldham had already expressed doubts regarding this correlation (p. 82, footnote).

that there is a stratigraphical gap answering to the whole of the Ranikot system of Sind, that is, the horizons of the "sables de Cuise," London clay, and Woolwich and Reading sands, as well as the cretaceo-tertiary passage zones such as the Thanet and Mons horizons of the Anglo-Parisian region.

The rocks immediately underlying the laterite are black sandstones full of volcanic material and crowded with fragmentary fossils. They represent the horizon of the Deccan Trap. They rest upon a vast thickness of white or whitish sandstones whose exposed surface weathers with a black crust: the huge blackened surfaces of the bedding planes dipping steeply eastward give to the Suleiman range, in this neighbourhood, a very peculiar and characteristic appearance when viewed from the plain to the east. The total thickness of these sandstones is considerable, exceeding 2,000 feet. They correspond with the Pab series, so called after the range of that name in Jhalawán, where they attain an enormous development. In Sind these rocks have been described as the "Cardita Beaumonti beds" owing to the leading fossil that occurs in the interbedded calcareous layers. In the neighbourhood of Fort Munro they are usually very massive, though some of the layers show a tendency to become shaly, when the rock becomes of a dark colour even on unweathered fractures, and assumes the characteristic appearance of the flysch formation. The flysch facies in Balúchistán is apt to invade formations widely differing in age, producing a sameness of appearance which, combined with the usually concomitant absence of fossils, has been a fruitful source of error in unravelling the stratigraphy of Balúchistán. The neocomian "belemnite beds", the uppermost cretaceous Pab sandstones, the lower lutetian Ghazij (coal-bearing series), the middle lutetian Lower Khirthar, and the oligocene series known under various names such as Nari, Gaj, Mekran, Kojak, Murree, etc., are all apt to assume the flysch facies, and have been forced into doing duty for one another by various geologists, the present writer included[1]. The most extensive and

[1] I may mention in particular the shales and sandstones north of the Zhob and Pishin valleys and in the Kojak range which have been shifted backwards and forwards from Cambrian through Carboniferous, Triassic, and Cretaceous to Eocene. I represented them as Eocene in my map of the Quetta, Pishin and Zhob regions in Vol. XXXI (Pl. 18) of these "Records", but have finally ascertained their oligocene age owing to the discovery of interbedded fossiliferous bands with oligocene foraminifera and clypeasters in the Zhob, Pishin, and Mekran districts (Vol. XXXIV, p. 89).

most typical flysch outcrops are those constituted by the oligocene Kojak shales; in this respect the geological features of Balúchistán agree with those of Europe where the bulk of the flysch formation is oligocene, although older rocks as well are at times affected by this particular facies.

The specimens collected by Mr. Lee-Mayer, Mr. Maynard, and Major Pirrie from the flysch-like layers of the Pab sandstones at Fort Munro include numerous specimens of those curious markings which, for many years, were described as the flysch algæ, until it was demonstrated by Nathorst (Om spår af några evertebrerade djur m.m. och deras paleontologiska betyldese, *Kongl. Svenska vetenskaps-akademiens handlingar*, Vol. XVIII, No. 7, 1881) that they are mostly tracks and trails of animals, or even mere impressions of organic or inorganic particles dragged over the soft mud or sand, or else furrows and pittings due to currents and eddies. The most numerous amongst the Fort Munro specimens appear to correspond with the structures described as *Tænidium* and a variety of other generic names, such as *Caulerpa*, *Phymatoderma*, *Harlania*, *Arthrocyphus*. Their exact attribution is of small consequence considering the vagueness and uncertain nature of many of these structures. They appear as bundles of cylindrical bodies with blunt rounded terminations (Pl. 31, figs. 2, 3). Occasionally these cylindrical bodies are very minutely wrinkled transversely, the best instance of this structure being exhibited upon one of Mr. Lee-Mayer's specimens (fig. 2). Specimens closely resembling those here represented have been figured by Th. Fuchs as *Caulerpa* (*Phymatoderma*) *arcuata* Schimper, from the cretaceous flysch of Rignano near Florence, and *Phymatoderma* sp. (Fucoiden and Hyeroglyphen, Pl. IX, figs. 1, 2, *Denkschr. d. kais. Akad. d. Wiss. math-naturw. Classe*, Vol. LXII, 1895). Of Fuchs' two specimens, the first one especially resembles the one collected by Mr. Maynard (Pl. 31, fig. 3), while the second is closely similar to Mr. Lee-Mayer's specimen (fig. 2). The exact nature of these fossils is uncertain. It has been suggested by Nathorst that they may represent the casts of annelid burrows, the transverse wrinkles being caused by rythmical contractions of the body.

Amongst the material collected by Mr. Maynard, there is an excellent specimen of the markings that have been classified in the group of the so-called Chordophyceæ. (Pl. 32, fig. 1). Many of these markings, according to Nathorst, are tracks caused by shrimps and

other crustaceans, not by crawling, but in the act of swimming quite close to and almost in contact with the sea-floor from which they derive gentle support without actually resting on it. Mr. Maynard's specimen is almost identical with the track of *Crangon vulgaris* experimentally obtained by Nathorst (*loc., cit.* Pl. 1, fig. 3). Mr. Maynard, who identified the specimen as a crustacean track, mentions that similar markings are very abundant at certain zones of the cretaceous flysch. The following spots are mentioned by Mr. Maynard as those where the specimens are most plentiful: (1) the ground west and south of the mosque below the bazar; (2) the Dhobi's Tank.

It has been ascertained by Nathorst that there is often no appreciable difference between tracks of animals belonging to widely different genera, and this explains the sameness exhibited by the supposed algæ from the earliest cambrian to the miocene mollasse. A glance at the illustrations in Heer's *Flora fossilis Helvetiæ* will show the complete similarity between many of the so-called algæ from the oligocene flysch and those from cretaceous rocks, so that many of these markings are of indifferent value as zone fossils.

In addition to tracks exhibiting distinct structures, the collections from Fort Munro include many slabs whose surface is crowded with indeterminate markings which often overlap one another in such a manner as to produce fantastic resemblances to dragon flies, spiders, etc. Similar markings abound in the flysch of Europe. A good example of one of these slabs is shown on Pl. 32, fig. 2. The original of this illustration was collected by Major Pirrie.

It is interesting to note that closely similar markings are found in the Vindhyan sandstones which, up to the present, have yielded nothing definite in the way of fossils. The surfaces of sandstone slabs at certain zones of the Vindhyan series in Peninsular India are profusely covered with such markings. For comparison with Major Pirrie's specimen, I have shown on Pl. 33 a slab of shaly sandstone of dark red colour from the horizon of the Sirboo shales, which I collected at Lilgar (Lat. 23°, Long. 78°1′) in Bhopal.

As in the case of the Pab sandstones, the Vindhyans also contain besides these indeterminate markings, some "chordophyceous" tracks exhibiting very definite structures. A beautiful example collected by Mr. T. D. LaTouche at Barui near Osia, 30 miles north of Jodhpur, is shown in Pl. 34. The fossil, forming a relief cast at the surface of a

slab of red sandstone, consists of a succession of swellings about 25 millimetres in width and 45 millimetres in length, somewhat recalling in shape an inflated wine skin or bagpipe, or a deflected urn; from the thicker end start thick tentacle-like filaments, one of which constitutes the stalk of the succeeding swelling. Throughout the greater portion of the specimen the swellings are better marked on one side than on the other, as if the animal that produced them had been crawling sideways. I have failed to identify this fossil with any figures of such structures to which I have had access [1].

Some of the slabs collected by Mr. LaTouche are covered with fusiform bodies identical in size and appearance with similar objects occurring in the Silurian of Portugal, and figured in his work on the Bilobites (Etude sur les Bilobites ..., Pl. II, fig. 1, 1886), by Delgoado, who regarded them as bearing some relation to the bilobite described as *Cruziana furcifera*, d'Orb.

The absence of identifiable fossils has often been adduced as an argument for referring the Vindhyan series to the pre-Cambrian period; but it may here be remarked that the statement frequently made as to the Vindhyan rocks being eminently suited to the preservation of fossils is misleading. The reasons given are that the formation is rich in limestones and that it is very little disturbed. On the one hand, rocks can be greatly disturbed with the development of slaty cleavage and even the crystallisation of secondary minerals without obliteration of the fossils, and on the other hand, the Vindhyan limestones belong to a class of rocks in which, so far as my experience goes, fossils are always rare or absent: there is an entire lack of the rubbly and porous limestones that usually yield fossils. The Vindhyan limestones are usually thin-bedded rocks, the fracture of which has a porcellanoid appearance, and which are often striped in bright tints of alternating red, or purple, or green.

[1] At page 30 of his Memoir on Western Rajputana (Mem., G. S. I., Vol. XXX, part 1, 1902) Mr. LaTouche has mentioned the tracks that cover the bedding planes of the Vindhyan sandstones at Osia. The specimens described are relief casts of straight or curved grooves; no mention is made, however, of the remarkable fossil here reproduced. Markings similar to those described by Mr. La Touche, but of rather smaller size, are to be seen on the Vindhyan slab represented on Pl. 34 of the present volume, and on the specimen from Fort Munro represented on Pl. 32, fig. 2.

They often pass into shales of similar texture. The presence of ripple marks on the bedding planes of the limestones show that they were deposited as a calcareous mud. I am unable to account for the exact manner in which such rocks have originated; they are very abundant at certain horizons of the Cretaceous and Eocene of Baluchistan, and are always nearly or quite devoid of fossils, even in these otherwise highly fossiliferous formations.

My colleague Mr. Hayden informs me that markings closely resembling some of the crustacean tracks of Fort Munro occur in great profusion in the Haimanta of Spiti, beneath the lowermost fossiliferous zone with *Lingulella*, amongst beds which cannot be newer than lower Cambrian. They also occur above the *Lingulella* zone, as has already been stated by Hayden (*Mem., G. S. I.*, XXXVI, p. 15).

I have correlated the sandstones underlying the Tertiary rocks of the Suleiman range with the Pab sandstones and *Cardita Beaumonti* beds of Baluchistan and Sind on account of their identical stratigraphical position, that is, passing conformably downward into the "Hemipneustes beds" which contain Maestrichtian and Campanian fossils, while they are unconformably overlaid by the Eocene. The presence of volcanic material is a point of some importance for correlation, basalts and volcanic ashes being frequent at this horizon, which corresponds with the Deccan Trap of the Peninsula. The fossils so far collected by Mr. Maynard from the laterite layer at the top of this formation are insufficient for purposes of correlation, and the remarkable tracks of crustaceans and other animals are, as already explained, uncharacteristic from a zonal point of view. Nevertheless, at a horizon which has not yet been determined, the sandstone contains some well-preserved characteristic fossils: I found numerous specimens of an *Orbitoides* which I identified as the Maestrichtian *O. minor* Schlumb. in some of the derived blocks which form the extensive talus of pleistocene accumulations that skirt the Suleiman range, and are everywhere largely developed in the arid regions of the north-west frontier and throughout Persia.[1] The staging bungalow at Rakhi Munh, in the neighbourhood of which

[1] For descriptions of the talus formation, see *Rec., G. S. I.*, XVII, pp. 189-190 (1884), XXV, p. 41 (1892), *Mem., G. S. I.*, XXXI, p. 41 (1901).

I obtained these specimens, stands on a terraced spur of these pleistocene accumulations. The appearance of the blocks containing the *Orbitoides* is not sufficiently characteristic to decide from what particular zone of the Pab sandstones they were derived, without a much closer study of the section than I could afford time to devote to it. It would be highly interesting if a geologist residing at Fort Munro could trace the exact horizon of the fossiliferous band. *Orbitoides minor* characterises the uppermost cretaceous of Maestricht, and its presence is therefore consistent with the correlation of the Fort Munro sandstones with the Pab sandstones of Jhalawan.

The Rakhi gorge, where it traverses the axis of the anticlinal arch, cuts through a magnificent section of the beds underlying the Pab sandstones. These are the dark shales and grey limestones that have been described in other parts of Baluchistan as the "Hemipneustes beds", whose age ranges from Campanian to Maestrichtian. In a few minutes' search I obtained recognisable specimens of *Orbitoides media* d'Archiac, *Holectypus baluchistanensis* Noetling, *Echinanthus Griesbachi* Noetling, and *Hemipneustes compressus* Noetling, all of which are characteristic fossils of the Hemipneustes beds. The exposures in the Rakhi gorge seem therefore to be richly fossiliferous and would well repay systematic exploration.

These are the oldest beds exposed in the neighbourhood of Fort Munro. The carriage road follows their outcrop for about three miles, after which the section reascends as far as the horizon of the Alveolina limestone, upon which stands the hill-station.

Further north the altitude of the Suleiman range increases together with the increase in the amount of upheaval, and where it culminates in the Takht-i-Suleiman and Kaisergarh, the anticlinal arch exposes, in addition to the beds visible at Fort Munro, a considerable thickness of strata of lower cretaceous, oolitic, and liassic age.[1] Nevertheless the easily accessible neighbourhood of

[1] A description of the Takht-i-Suleiman illustrated with magnificent panoramic views has been published by Griesbach in these Records, Vol. XVII, pp. 175-190 (1884), and a detailed geological map of the range by La Touche in Vol. XXVI (1895). Both authors have been misled by attempting to fit the stratigraphical correlation into Blanford's scheme. This, however, does not affect the accuracy of the boundaries shown on their maps and sections. All that is needed is to

Fort Munro teems with objects of geological interest, and it is to be hoped that the observations here recorded will be the prelude to further valuable researches.

shift some of the names of the geological groups a degree or two higher. Thus in the tabulated list of the Suleiman range formations, at page 82 of LaTouche's Memoir, the beds should be correlated as follows: 1, massive limestone, middle jurassic; 2, belemnite shales, and 3, Parh limestones, neocomian; 4, Hemipneustes beds, campanian to maestrichtian (the "nummulite" mentioned is the nummuliform *Orbitoides media*); 5, Pab sandstones, maestrichtian to danian; 6, probably the Alveolina limestone, lower lutetian; 7 and 8, Ghazij shales, lower Lutetian flysch; 9 to 11, either the upper part of the Laki formation of the Lower Khirthar, the published fossil determinations being insufficient to settle which of the two; in either case the age is lutetian; 12, oligocene flysch; 13 and 14, Siwaliks, upper miocene to pliocene; 15, pleistocene and recent. The discovery of the oligocene age of zone 12 is due to my colleague Mr. G. H. Tipper, who latterly collected from these strata a number of fossils which he determined as Nari or Gaj in age. Mr. Tipper's discovery finally disposes of Blanford's assertions as to the non-existence of marine oligocene beds in the Suleiman range (*Mem. G. S. I.*, XX, pp. 108, 109, 159, 160). The old collections of the Calcutta Museum also contain marine oligocene fossils from the Salt Range. Since 1901 I established the existence of marine oligocene beds in the Pishin and Upper Zhob districts (General Report for 1901-1902, p. 12; *Rec., G. S. I.*, XXXI, p. 162, 1904, XXXIV, pp. 268-271, 1907). Noetling discovered marine oligocene beds in the Lower Zhob in 1898 (General Report for 1898-1899), p. 62. Lastly I have shown that the greatest part of the flysch, the marine formation most widely spread throughout Baluchistan, is oligocene (*Rec., G. S. I.*, XXXIV, pp. 89-90, 181).

LIST OF PLATES.

PLATE 31, FIG. 1.—Fossil fruit from the laterite bed forming the upper limit of the Pab sandstones at Fort Munro; collected by Mr. H. J. Maynard. 1*a*, section of the same fossil.

FIG. 2.—*Phymatoderma* from the Pab sandstones of Fort Munro, collected by the Reverend Mr. Lee-Mayer.

FIG. 3.—*Phymatoderma* from the Pab sandstones of Fort Munro, collected by Mr. Maynard.

All the figures slightly enlarged in the proportion of about 47 to 44.

PLATE 32, FIG. 1.—Crustacean track from the Pab sandstones of Fort Munro, collected by Mr. Maynard. Natural size.

FIG. 2.—Slab from the Pab sandstones of Fort Munro, collected by Major F. W. Pirrie. Slightly enlarged in the proportion of about 47 to 44.

PLATE 33.—Slab of Vindhyan sandstone from the horizon of the Sirboo shales, collected by E. W. Vredenburg at Lilgar (Lat. 23°, Long. 78° 1') in Bhopal, Central India. Slightly enlarged in the proportion of about 47 to 44.

PLATE 34.—Slab of Vindhyan sandstone collected by T. D. LaTouche at Barui near Osia, 30 miles north of Jodhpur, Rajputana. Length of slab: 33 centimetres.

JADEITE IN THE KACHIN HILLS, UPPER BURMA. BY A. W. G. BLEECK, PH.D., F.G.S., CALCUTTA. (With Plates 35 to 39.)

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TO judge by the long list of publications our knowledge of Burmese jadeite should practically be complete, and yet there are numerous problems relating to the mode of occurrence and the genesis of jadeite which have not been solved satisfactorily. Most of the previous authors have based their views on the statements made by Dr. F. Nöetling, the only other geologist who has visited the jade-mines at Tawmaw. Dr. Nöetling's survey of the jade-mines district, however, was incomplete, as he is careful in pointing out himself, owing to the fact that the unsettled state of the country and the impenetrable

jungle impeded him in his work. I had to contend with the same difficulties, and although the jade-mines themselves offer every opportunity for detailed petrographical investigation, the geology of the surrounding country could not be satisfactorily surveyed. A careful combination, however, of all the observations helps one to give a fairly good idea of the geological features of the district. The places visited on tour were Manwe, south of Kamaing on the Indaw chaung; Naniazeik, due west of Kamaing; Kansi, Lonkin, Mamon, and Houngpa, all on the Uru chaung; Tawmaw and Hwéka, the former north and the latter south of Mamon.

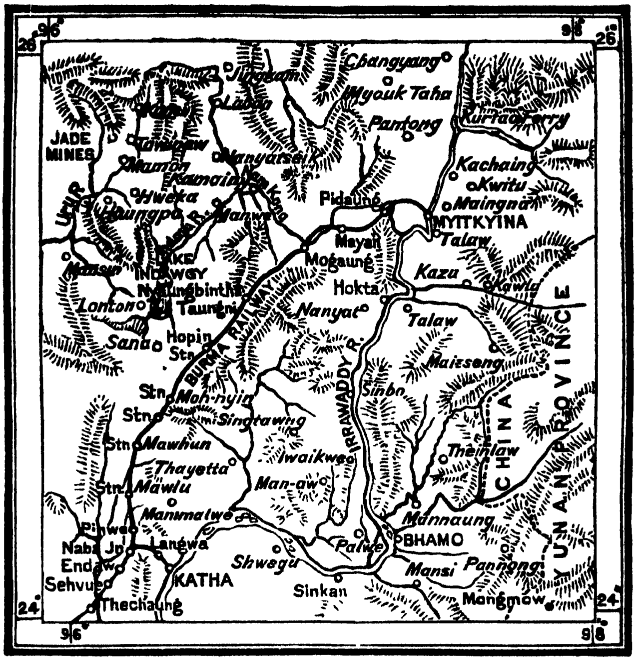

Fig. 1.
Sketch-map of part of Upper Burma.
Scale 1 in. = 32 miles.

Jadeite is found at three places in the Kachin Hills—at Tawmaw, at Hwéka, and at Mamon. The quarries and mines at Tawmaw are undoubtedly the most interesting. Tawmaw is situated on a plateau approximately 3,000 feet high. This plateau is about 10 miles long stretching from north to south; its breadth, however, does not exceed one mile. The jadeite, associated with other minerals, occurs in a

dyke of igneous origin. This dyke is intrusive into the serpentine, which is the predominant rock on the plateau. The mines and quarries cover an area of ground approximately 500 yards long and 200 broad. (Pl. 35, fig. 1.) Twelve shafts have been sunk on the jadeite dyke and are being worked. These numerous shafts and inclines represent different claims, which are let out to Chinese traders by the owner of the jade-mines, a Kachin chief. Underground the workings are connected up. Some of course are considerably deeper than others. Mining-methods have not changed since Dr. Nöetling visited Tawmaw in 1892. The fire-process for cracking the rock is still in vogue exactly as previous authors have described it.

These mines are only worked about three months in the year from the beginning of March till the end of May; during the rains malaria fever stops all work. In January the Kachins begin to bail the mines which fill up with water completely during the time they are not worked. This laborious task takes nearly two months to complete. Day and night a few score Kachins are at work bringing up the water in kerosine-oil tins. After the bailing is completed the mines are in a dangerous condition, and nearly all the complicated timbering has to be renewed (Pl. 35, fig. 2). On the occasion of my first visit to Tawmaw all the shafts were under water, and I had to content myself with specimens picked up from the dumps. A month later, however, I re-visited the place and, the mines being dry by this time, I was able to study the jadeite *in situ*.

At Hwéka jadeite occurs in the shape of boulders in a conglomerate. Jadeite-boulders are not very plentiful, but sometimes very large and, to judge by the crowd of Chinese buyers assembled at Hwéka at the time of my visit, quarrying must be very remunerative. The quarries are situated on the steep slopes of a fairly high hill north of Hwéka, and as there is no deep mining and consequently no accumulation of water in the workings, the season for the jade-miner starts much earlier at Hwéka than at Tawmaw (Pl. 36, fig. 2).

The third jadeite-producing place in the Kachin Hills is Mamon. The mineral is found in the shape of boulders in the alluvial deposits of the Uru chaung as well as in the bed of the river itself. Many years ago jadeite-boulders were found all along the upper reaches of the Uru as far as Sanka. All these workings, however, have been abandoned with the exception of those in the immediate neighbourhood of Mamon.

The geological features of the country west and north of the Indaw chaung do not appear very complicated (Pl 39). The high ranges of mountains between Manwe and Naniazeik are almost entirely composed of granite. In several places I traced irregular masses of crystalline limestone surrounded on all sides by this granite. The marble is generally of a pure white colour. In many places it contains crystals of graphite, chondrodite, forsterite, phlogopite, etc. These minerals were developed by contact metamorphism of limestone by intrusive granite. It is significant that at many places the Kachins have washed for corundum in the numerous little streams which come .rom these mountains. Furthermore, ruby-mines were formerly worked near Naniazeik.[1] Corundum is a specific contact-mineral in crystalline-limestone, and there can be no doubt that the abovementioned marble is the matrix, which originally contained the corundum. From the fact that ruby-mines are known to exist 11 miles north of Naniazeik I gather that granite and crystalline-limestone continue in this direction. Six miles to the north-west of Naniazeik, however, serpentine sets in and forms range upon range as far as Kansi and even beyond the Sanka chaung. These serpentine-hills are all very much alike, with steep sides crowned by long and narrow plateaus.

In a few localities a basic igneous rock belonging to the family of the basalts was found and, as will be shown later on, it represents a type called picrite-porphyry. Serpentine and an occasional boss of this picrite-porphyry were traced as far south as Nanion.

South of Nanion the landscape changes, the hills becoming much lower, and the slopes gentler. These low ranges are entirely composed of a bluish grey sandstone, which sometimes gives way to a coarse conglomerate. Identical rocks were found at Hwéka, where the conglomerate is rich in boulders of jadeite. Both sandstone and conglomerate are interstratified with very thin seams of coal. Some very badly preserved casts of dicotyledon-leaves were collected. Mr. J. Schuster very kindly determined them as belonging to a new species of *Laurus*, which he called *Tetranthera Hwékonsis*. These leaves are of some importance, as they prove the Tertiary age of the sandstones and conglomerates. In all probability these strata are identical with the miocene strata, which Dr. Noetling mentions in this paper on jadeite in the Kachin Hills. Although the country lying between

[1] For an account of these mines *see* Records, Geol. Sur., India, Vol. XXXVI, Pt. 3, p. 164.

Hwéka and Nanion could not be surveyed it is very probable that these Tertiary strata continue as an uninterrupted series of rocks from Nanion as far as and even beyond Hwéka to the south. The Tertiary strata show considerable faulting.

West of Hwéka serpentine sets in again and continues on as far as Houngpa on the left bank of the Uru chaung. On the western slopes of these serpentine-hills overlooking the river several almost horizontal terraces of brown iron-ore occur, which are of a very interesting nature. This is not laterite, for which one is at first inclined to take it, but undoubtedly an iron-ore formed by precipitation from aqueous solution and must therefore be termed bog iron-ore or lake-ore.

North of Mamon on the left bank of the Uru, I came across a series of "crystalline schists." These schists appear to form a small isolated occurrence bounded on one side by the Uru and on the other three sides by the Tertiary strata. They correspond to the crystalline schists occurring on the right bank of the river.

These latter form the slopes of the range leading up to Tawmaw. Near the crest the crystalline schists suddenly stop, and again the serpentine forms the plateau. Crystalline schists of nearly identical outward appearance occur again on the western slopes of this mountain range.

The mineral resources of the jade-mines districts are, with the exception of jadeite, of no economic value whatever. Ruby-mining at Naniazeik and Manwe has never been done at any profit, although systematic prospecting of the whole ruby and corundum tract may lead to favourable results. In the upper reaches of the Uru chaung Kachins wash for gold. The work, however, can hardly be termed remunerative. The coal-seams never exceed an inch in thickness and are therefore absolutely worthless. Chromite occurs in the serpentine near Tawmaw, but not in sufficient quantity for exploitation.

In the following pages I shall deal with the petrology of the country surveyed. Six different groups of rocks will be treated in the following order:—

1. The granite and crystalline limestone west of the Indaw chaung between Naniazeik and Manwe.

2. The serpentine and basic eruptive rocks lying between the Sanka chaung and Naniazeik.

3. The Tertiary sandstones and conglomerates between Nanion and Hwéka.

4. The serpentine and bog iron-ore west of Hwéka.

5. The "crystalline schists" on the left bank of the Uru chaung.

6. The serpentine and "crystalline schists" on the right bank of the Uru chaung. (Tawmaw series.)

Dr. F. Nöetling makes no mention whatever of the granite hills between Naniazeik and Manwe. The granite shows the usual varieties of coarse and fine grain. Dark crystalline concretions composed particularly of the more basic constituents of the rock are very abundant. Numerous veins of aplite and pegmatite traverse the granite. These bosses of granite enclose large masses of crystalline limestone. Both granite and marble and their relations to the ruby tract of Naniazeik and Manwe have been treated in a separate essay[1].

The most important of the second group of rocks is the serpentine. Specimens collected on the march from Naniazeik to Kansi all closely resemble one another. A slight difference in colour is produced by weathering, the colours varying from dark-green to brown-green. Magnetite and chromite occur as dark concretions or tiny ill-defined veins throughout the rock. The microscope proves the rock to be normal serpentine. Fresh olivine is only contained in one slide and shows its normal properties. It occurs in irregularly shaped grains traversed by fine cracks. On these cracks the olivine has been altered into fibrous chrysotile, resulting in characteristic reticulated mesh structure. Chromite occurs as inclusions in the fresh olivine and is besides finely disseminated throughout the whole mass of serpentine. Magnetite is undoubtedly of secondary origin, as it only shows in the "serpentine minerals". Occasionally both chromite and magnetite occur in octahedral crystals, but more often they form irregular little patches and grains. Other slides revealed just a few tiny grains of olivine, the alteration into serpentine being in a very advanced stage. In this case, however, the serpentine-minerals are chiefly antigorite. Between the fibro-lamellar masses of antigorite representing the first generation of this mineral a second generation of antigorite was formed, which is so dense that it remains perfectly dark between crossed nicols. Other slides of serpentine contained simply bastite and a few grains of chromite and magnetite. It is very probable that

[1] *Supra*, p. 168.

this bastite owes its origin to a paramorphic transformation of non-aluminous amphiboles, and several remnants of tremolite found in the bastite tend to corroborate this statement. Another slide contained, besides antigorite and the abovementioned ores, several irregular aggregates of magnesite or ferrous carbonate.

North-west of Nanion I came across some basic eruptive rocks closely resembling basalt. These rocks form low hills which for the most part are unapproachable on account of the dense jungle. A couple of specimens were taken and proved very interesting. It is a hard grey rock, compact and homogeneous in texture. It breaks with a splintery fracture. The only constituent minerals which present themselves to the naked eye are numerous black needle-shaped crystals of rhombic pyroxene in an undeterminable light grey groundmass. Examined in slides under the microscope the groundmass is seen to consist of a plagioclase felspar, determined as labradorite by Fouqué's method. Besides the felspar tiny crystals of pyroxene could be distinguished in the groundmass. The same pyroxene, augite, occurs in larger patches. Besides augite large crystals of rhombic pyroxene are abundant. They show signs of magmatic corrosion and contain numerous inclusions of magnetite. The magnetite crystals have, as is generally the case, ranged themselves in lines along the successive zones of growth. The only accessory minerals observed were a few needle-shaped crystals of apatite and numerous small crystals of magnetite. The essential difference between a normal basalt and the rock described is the preponderance of pyroxene over the felspar. On comparing the latter with picrite-porphyries from Anina in Hungary, where this type of rock was first found and studied, the resemblance between the two was proved to be so pronounced, that the basaltic rocks found in the Kachin Hills must also be classed as picrite-porphyries. Professor M. Bauer describes a normal basalt, which was discovered by Dr. Nöetling 4 miles east of Sanka. Unfortunately I could not trace this occurrence, but there can be very little doubt that Bauer's basalt and the abovementioned picrite-porphyry represent two closely connected types of basic rocks belonging to one period of contemporaneous eruptions.

In the vicinity of one of the picrite-porphyry hills on the road from Nanion to Kansi I came across a type of rock which outwardly resembles a silicified sediment. It is of a light brown colour and

very hard, and appears to be entirely composed of long parallel columns of quartz cemented by chalcedony. The columns of quartz consist of a string of tiny nodules of this mineral, and in between this quartz there lie sphærulitic aggregates of chalcedony.

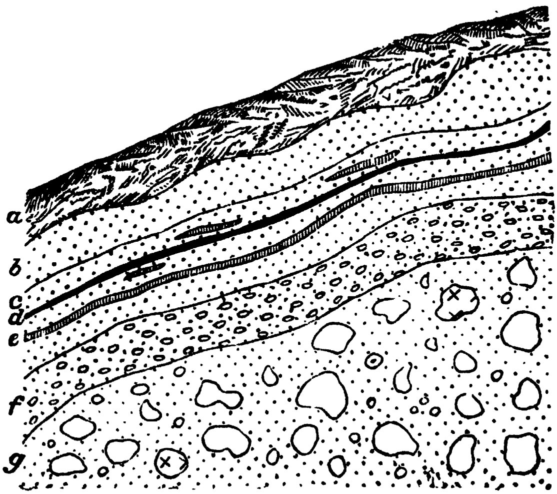

Fig. 2.

Section of the Tertiary beds at Hwéka.

a. Surface soil. *b.* Grey sandstone. *c.* Sandstone with carbonaceous shale. *d.* Coal seam. *e.* Carbonaceous shale. *f.* Conglomeratic sandstone. *g.* Conglomerate with boulders of jadeite ×.

The third group of rocks under discussion are the Tertiary sedimentary strata. Both the sandstones and conglomerates enclose short and thin coal seams and layers of coaly shale. Fig. 2 represents a section across the quarries at Hwéka. The colour of the sandstones and conglomerate is bluish-grey. The thickness of the sandstone beds must be very considerable, to judge by the profiles exposed on the cuttings of the new P. W. D. road from Lonkin to Naniazeik. The sandstones gradually pass into conglomeratic sandstones and finally into a coarse conglomerate. The microscopic study of these rocks revealed the following component minerals: quartz, calcite, serpentine, plagioclase, glauconite, chlorite, and an amorphous dark organic substance. Quartz and glauconite are predominant. In

no instance could any signs of metamorphism be discovered, the sandstones, etc., bearing a perfectly normal and unaltered aspect. As a "jadeite-deposit" of considerable economic value the conglomerate attracts our especial interest. The numerous well-rounded large and small boulders of rock which make up the conglomerate consist chiefly of serpentine, quartz pyroxenite, saussurite-gabbro, and an occasional boulder of jadeite. The cementing matrix is a hardened clay of a dirty green colour. The mineral composition of this clay is identical with that of the sandstone. The quartz-boulders appear to consist of quartz only, and were undoubtedly derived from quartz-veins. Slides of this quartz revealed the presence of a little muscovite and rutile. Boulders of saussurite-gabbro are fairly plentiful. The colour of the rock is a dark brown or grey. One of the chiet constituent minerals is a species of hornblende which occurs in large corroded crystals. In thin sections these are light brown in colour and strongly pleochroic. The other important constituent is the dull white substance known as saussurite. By microscopic examination it resolves into a confused and intimate aggregate of granules and fibres of clinozoisite, epidote, albite, and garnet. Of accessory minerals rutile alone is present. One slide showed the interesting phenomenon of a thin vein of felspar traversing the rock The felspar is both orthoclase and andesine. In structure the vein resembles the bostonites. The pyroxenite is a very coarse grained brown bronzitite. The constituent minerals are rhombic pyroxene, bronzite, and some accessory magnetite. The serpentine is of a dirty green colour and shows all the typical characteristics of this class of rocks. It consists of fibro-lamellar antigorite with accessory magnetite and chromite. It also contains numerous crystalline aggregates of magnesite and ferrous carbonate.

The presence of boulders of jadeite, serpentine, etc., in the conglomerate proves conclusively that the geological age of these strata is younger than that of the surrounding masses of serpentine, and that therefore the latter could not have been intrusive into the sandstones, etc.

The fourth group of rocks consists of serpentine and bog iron-ores. The serpentines present no new or remarkable features. They set in approximately two miles west of Hwéka and again form long ridges or plateaus. The bog iron-ores outwardly resemble laterite, but their mode of occurrence (in broad horizontal terraces) and chemical

composition leave no doubt as to their origin. The following is an analysis of the ore :—

SiO_2	1·63
Fe_2O_3	77·54
Al_2O_3	7·37
P_2O_5	Traces
H_2O	13·46
	100·00

Generally bog iron-ore contains more than "traces" of P_2O_5. This, however, cannot be taken as proof against the theory of precipitation from aqueous solution.

The group No. 5 represents a series of crystalline schists. They vary in outward appearance as well as in mineral composition, but nevertheless belong to a continuous series, the different types gradually passing into each other. The various types were found in the following order, descending from the crest of the hill. The topmost is a dark green chlorite-schist containing beautiful crystals of magnetite. The chlorite-schists give way to an actinolite-schist, containing small crystals of iron-pyrites, and towards the foot of the hill these gradually pass into glaucophane-schists. The chlorite-schists consist of a dark green scaly aggregate of chlorite, the ferruginous variety ripidolite, in which lie embedded beautifully perfect disseminated octohedra of magnetite. The actinolite-chlorite-schist is also of a dark green colour, but more granular in its texture. The actinolite occurs in long prisms and needles. Small crystals of iron-pyrites are fairly abundant. The groundmass again consists of ripidolite. This actinolite-chlorite-schist passes over gradually into a pure actinolite-schist, whereupon follow the glaucophane-schists. Of the latter two varieties can be distinguished. The glaucophane-schists near the actinolite are hard, compact, bluish-grey rocks, which break with a splintery fracture. The component minerals, as determined with a microscope, are glaucophane and a pyroxene closely resembling diopside, ilmenite with inclusions of rutile, garnet, and epidote. Pyroxene and glaucophane are predominant, the latter disseminated through the rock in large ragged patches showing the typical pleochroism in light blue and violet colours. The pyroxene appears to constitute a species of groundmass in this rock. In thin sections its colour is a very light green, and it contains numerous liquid inclusions. Shapeless grains of sphene with inclusions

of rutile are of very common occurrence in these rocks. Almandine is also present, though not very plentiful. It contains numerous inclusions of pyroxene and epidote. Another specimen of glaucophane-schist found at the base of the hill is remarkable for its absence of pyroxene, which occupies such an important position in the mineral composition of the first glaucophane-schist. The only predominant mineral here is glaucophane. Muscovite and epidote are fairly abundant. Iron pyrites in small crystals re-appear as an accessory, whereas garnet disappears altogether. Two very thin veins of felspar were seen to traverse this rock. These veins are undoubtedly of igneous origin, and show signs, such as the development of epidote, of having metamorphosed the rock they invaded. The felspar is both orthoclase and andesine. A similar phenomenon, it will be remembered, has been described as occurring in a boulder of saussurite-gabbro found at Hwéka.

The term "crystalline-schists," which has been employed to designate this whole group of rocks, has no bearing whatever on their real nature. From their general appearance and mode of occurrence they must be classed as metamorphic rocks. "Crystalline-schists" closely resembling those above described have been studied in many countries, and it has been proved conclusively that they originated from basic igneous rocks such as gabbro, diorite, etc., which have been completely metamorphosed in contact with granite. Although in this case the acid igneous rock, which should be held responsible for contact metamorphism, could not be traced at the surface in the vicinity of the crystalline-schists, it may exist at no great distance beneath it. There are in fact indications, such as the microscopic veins of felspar, that an intrusive mass of acid igneous rock does actually exist. The origin of the crystalline-schists cannot be explained otherwise than by contact; metamorphism produced in basic igneous rocks by intrusive granite.

The last group of rocks (No. 6) to be discussed, is of the greatest importance in connection with the origin of the jadeite at Tawmaw, and will therefore be treated in detail. In order to be able to refer to each single rock, they will all be numbered separately.

No. 1. Saussurite-gabbro.—A hard compact dark green rock with light spots. The component minerals as determined with a microscope are (albite) saussurite, *i.e.*, albite, clinozoisite, epidote, and prehnite, and, besides these, chlorite, actinolite, and titanite. The light spots represent the saussurite. The clinozoisite contained in the saussurite

often shows the peculiarity that the peripheral layers are developed as epidote. The saussurite is embedded in a groundmass consisting of clinochlore and actinolite.

No. 2. Saussurite-gabbro.—This specimen differs from No. 1 chiefly in its megascopic appearance. It has a decidedly schistose character and is of a lighter green colour. This is most likely due to far more numerous although much smaller light spots, which again represent patches of saussurite. The only difference in its microscopic features is that the albite shows lamellar twinning and a cataclastic texture.

No. 3. Saussurite-hornblende-gabbro.—This is a hard, compact, dark grey rock studded with numerous red garnets. Lighter spots representing saussurite are not discernible, dark minerals being predominant in the groundmass. An amphibole is the chief constituent of this rock. In thin sections this amphibole shows greyish green colours and strong pleochroism. Garnet is widely distributed throughout the rock, but never occurs in well-defined crystals. Saussurite-minerals are not nearly as plentiful as in Nos. 1 and 2. The clinozoisite does not polarize in the characteristic anomalous blue and yellow colours, but shows more normal grey and blue colours between crossed nicols, as is the case with ferruginous varieties of this mineral. The albite contains numerous liquid inclusions. Titanite and rutile are very numerous. Neither of these two minerals are bounded by crystallographic contours, but generally possess irregular and indented outlines. Professor Bauer describes a rock in his treatise on jadeite in Burma which he calls an albite-hornblende-schist. The essential difference in the mineral composition of Professor Bauer's albite-hornblende-schist and the saussurite-hornblende-gabbro is the presence in the former of albite without the other typical saussurite minerals. A rock corresponding to the one Professor Bauer describes was not found by myself, and I am therefore at a loss where to place it.

No. 4. Saussurite-gabbro.—This is a schistose rock of pale dirty green colour and splintery fracture banded by streaks of dark green chlorite minerals. The component minerals are the same as those described in Nos. 1 and 2. The chlorite was determined as clinochlore.

No. 5. Saussurite-glaucophane schist.—This is a hard and compact rock of greenish grey colour. Plagioclase in various advanced stages of saussuritisation and aggregates of quartz grains

showing a cataclastic structure are the essential constituent minerals. Large patches of a strongly pleochroic blue and green amphibole are fairly abundant. This mineral is richer in soda than the ordinary glaucophane and is consequently more strongly pleochroic. It will, however, still be termed glaucophane. Epidote, clinozoisite, albite, and clinochlore represent the saussurite minerals. Titanite and iron pyrites occur as accessories.

No. 6. Chlorite-schist.—This is a dark green, soft, scaly rock. It is composed entirely of clinochlore and numerous accessory titanite-crystals, showing an outer zone of decomposition. determinable as leucoxene.

No. 7. Quartz (from a quartz-vein).—This is a light grey, hard and splintery rock, almost entirely made up of quartz. In thin sections the quartz shows a typical cataclastic structure evidenced by undulatory extinction between crossed nicols. The slide also contains several thin laminæ of muscovite and a little accessory rutile and iron pyrites.

No. 8. Granite.—This is a hypidiomorphic rock of light colour, an unmistakeable granite. Quartz and felspar, both orthoclase and plagioclase, biotite, and a dark amphibole are the constituent minerals which present themselves to the naked eye. Under the microscope the quartz is seen to contain innumerable minute worm-like inclusions of plagioclase felspar, a phenomenon termed "quartz vermicule." Of the felspars orthoclase is the predominant one. The plagioclase is oligoclase-andesine. The amphibole is the common brown green variety. A dark brown strongly pleochroic mineral showing a feeble double refraction was determined as orthite.

The serpentine found at Tawmaw is quite similar to the serpentines previously described. The chromite, which occurs in pockets and bands, is fairly abundant, but not sufficiently so to warrant economic exploitation.

The mode of occurrence of the serpentine and the crystalline schists is as follows. The serpentine forms a long narrow ridge on the crest of the spur. On either side to the east and west the crystalline-schists Nos. 1, 2, 3, 4, 5, and 6 were found in corresponding order. On the western slopes Nos. 1, 2, 3, and 4 were successively traced. On the eastern slopes the garnetiferous saussurites were not found, their place being taken by glaucophane-schists, No. 5. Chlorite-schists, No. 6, were discovered in the north. Granite,

No. 8, and veins of quartz, No. 7, traverse these rocks in all directions.

An interesting collection of rocks associated with the jadeite was made at the quarries of Tawmaw. First comes a rock which varies in colour from pure white to light grey. It is hard and compact, and breaks with a splintery fracture. The most remarkable feature of this rock is its close resemblance to jadeite. It actually shows the light green spots exactly like the jadeite and is translucent in a very high degree. In most cases it is perfectly impossible to tell the difference between jadeite and this rock. The marked difference of specific gravity alone can prove the one jadeite and the other a rock of different mineral composition. Numerous specimens of the latter rock were collected as jadeite, and not until a careful microscopic and chemical investigation had been made could such specimens be identified as "pseudojadeite." These investigations were based on numerous tests of specific gravity, that of jadeite being 3·338 and that of the "pseudojadeite" 2·577. The microscope revealed the true nature of the pseudojadeite. The rock consists of felspar alone, which is so highly cataclastic that it becomes a difficult task to single out a suitable individual piece for optical identification. The felspar was determined as albite. The chemical analysis proves the correctness of these observations:—

SiO_2	67·10
Al_2O_3	20·42
Fe_2O_3	0·23
K_2O	3·20
Na_2O	8·93
	99·88

In places where this albite rock was exposed to weathering it has lost its vitreous lustre and has become a dull milky white. Several specimens of this albite rock have a banded and streaky appearance, the colours running from pure white to grey and pale green. On close examination it was found that thin layers of amphibole schists produce this effect. These same amphibole schists also occur as large lenticular inclusions in the lighter rock.

A second species of rock found in the quarries at Tawmaw is an amphibole schist. Its colour is a dark green, and it varies in texture from a coarsely crystalline to a fibrous variety. The latter varieties

give a beautifully foliated fracture. Microscopic investigation proves the rock to consist entirely of actinolite, the mineral either occurring in ribbon-like fibres and long needles or in broad prisms and blades. The bent and contorted crystals, which show unmistakeable signs of crushing, evidence a typical cataclastic structure. A rare constituent of this rock is a species of chlorite showing strong pleochroism in rich green colours. The latter property is due to a slight admixture of chromium which replaces iron in the chemical constitution of the mineral.

A third rock which is very similar to the last one described is solely composed of an amphibole rich in soda. This mineral is a member of a graduated series of soda-amphiboles, which both as regards their chemical constitution and their optical properties lead up to glaucophane. In thin sections the mineral is characterized by its marked pleochroism, its anomalous polarization colours, strong divergence of the optic axes, oblique extinction, and a zonal structure. The glaucophane-schists described by Professor Bauer in his paper on the jadeite and other rocks from Tawmaw are undoubtedly identical with these. The same rocks are generally found in contact with jadeite and for the most part are coarsely crystalline. They gradually pass into actinolite-schists.

Albite in contact with the amphibole schists was studied by the aid of several slides. In each case the amphibole was actinolite and not, as in contact with jadeite, a soda-amphibole. The slides proved conclusively that the albite-rock is intrusive into the actinolite, as small veins of albite are seen to run through the latter in all directions.

Another rock which is fairly abundant in small pieces at the jade-mines excited considerable interest. The colour is a beautiful dark green, and its texture is very hard and compact. Apart from a few small crystals of chromite it is composed of only one mineral which, however, defies megascopic determination as it never occurs in the shape of individual crystals. The microscope shows it to be a member of the epidote-group. Its index of refraction, cleavage, hardness and specific gravity are identical with the common epidote. The colour in thin sections is a beautiful emerald green. Pleochroism is very strong (α-γ emerald green, β bright yellow). The optic axial angle is nearly 45°. Between crossed nicols one observes bright green and red interference colours. The texture of the mineral in thin sections varies considerably. The mineral sometimes appears in aggregates of small

grains and sometimes in laminæ closely resembling mica. This remarkable phenomenon must have been produced by mechanical deformation. The following is a chemical analysis of the mineral:—

SiO_2	37·92
Fe_2O_3	9·93
Al_2O_3	12·83
Cr_2O_3	11·16
CaO	25·35
H_2O	2·38
	99·57

Analysis of the common epidote shows a higher percentage of Fe_2O_3 and Al_2O_3. In this mineral Cr_2O_3 evidently replaces its equivalents of Fe_2O_3 and Al_2O_3 and becomes an important factor in the chemical constitution of the mineral. Undoubtedly this mineral represents a new and distinct member of the epidote group, hitherto unknown to science. As an appropriate name I suggest *Tawmawite.*

The most important of the Tawmaw series of rocks is of course the jadeite. Information concerning the annual production and value of jadeite found in Upper Burma will be found in A Review of Mineral Production in India, 1898 to 1903, by Dr. Holland, Records, Geol. Survey of India, Vol. XXXII, Part 1. Jadeite is purely an ornamental stone and as such is exclusively prized by the Chinese, who import it into China for the manufacture of ornaments and articles of personal adornment. Taken on the whole jadeite is very expensive. "Very small pieces of jadeite of the purest colour and best quality sometimes fetch fancy prices, while great blocks of inferior quality have little or no value in the connoisseur's eyes" (Investigations and Studies of Jade). The Burmese and Kachin name for jadeite is *Chauk-sen;* the Chinese name is *Yu-esh* or *Jeits-ui*. (This name is derived from a kingfisher, the peacock-green plumes of which they often use inlaid on jewelry.)

In the following remarks jadeite will only be treated from the mineralogical and petrographical point of view. Jadeite is a very hard, compact and tenacious rock. Generally speaking it is cryptocrystalline in structure, but comparatively coarse-grained varieties are by no means rare. The fracture is close grained and splintery. Very often the rock breaks up into plates with perfectly parallel cleavage planes. The colour of pure jadeite is a stainless white. Specimens of pure

white jadeite very closely resemble marble. The specific gravity however and vitreous lustre distinguish jadeite from the latter. The green varieties of jadeite are those which are most sought for. Valuable pieces of green jadeite are by no means abundant as compared with the white variety. Green jadeite occurs as inclusions in the white, varying in size from tiny spots up to lumps, weighing two or three viss.[1] A narrow zone of graduated lighter green tints mediates between the pure white and the darker green shades. The white jadeite with emerald green spots has by previous authors been termed characteristic for the occurrence of jadeite in Burma. There are two varieties of green jadeite, the colour of the one being a bright emerald green, the colour of the other a dark dull green. Another tint, which, however, is not met with often, is a pale amethystine colour. "The colorific agents to which jadeite owes these different hues are mainly the compounds of iron, manganese, and chromium. Manganese is relatively unimportant" (Investigations and Studies of Jade). Chromium is undoubtedly the source of the brilliant emerald green colours in jadeite. Iron imparts the dull green colours to the mineral, whereas the amethystine tint has been ascribed to the presence of manganese. Free oxides of manganese and iron as well as chromite in small amounts are said to produce a greyish tint in jadeite. A red variety of jadeite was formerly found embedded in the alluvial soil in the valley of the Uru river. The staining is undoubtedly of secondary origin. Approximately seven different kinds of jadeite are distinguished by the Chinese traders. The best jadeite is called *Mya-Yea-Chauk*. The colour is a bright emerald green. *Shwe-Lu* comes next; the green colour is not as bright as that of *Mya-Yea-Chauk*. The third variety is called *Lat-yea*; the colour is a dull clouded green. This variety is obtainable in comparatively large pieces and is fairly abundant. A fourth variety, *Hmawsit-sit*, which fetches very good prices, is dark green in colour but absolutely opaque. *Kon-pi* is the red variety. *Chauk-tha* and *Pan-tha* are two different qualities of white jadeite. The former is a dull white; the latter a brilliant white with strong vitreous lustre.

In mineralogy jadeite is regarded as a member of the pyroxene group. Individual crystals of jadeite have not been found up to date. The usual mode of occurrence is a crystalline aggregate of

[1] A viss = 3·65 lbs.

more or less density. Jadeite rock examined in slides under the microscope consists of numerous interwoven prisms and needles of pyroxene. In its internal structure the jadeite is generally highly cataclastic, the individual needles and prisms being bent, broken, and crushed into small fragments. Strain-shadows (undulose extinction) were frequently observed. Polysynthetic twinning as the result of crushing has also been recorded. The twin-planes evidently coincide with the gliding-planes. "We must conclude therefore that under favourable conditions crushing and pressure would produce in the jadeite a re-arrangement of the molecules into twins similar to that observed in calcite." The angle of prismatic cleavage has been given by Krenner as 86° 55′ and by Arzruni as 86° 56′ to 87° 20′. White jadeite is colourless in thin sections, whereas the green jadeite shows very light green tints. It has, however, been proved that the colouring produced by chromium alone remains visible in slides.

The following is a short abstract from the chapters dealing with the optical properties of jadeite as recorded by Professor Iddings in "Investigations and Studies of Jade." "The long prisms are well developed in the prismatic zone and have the orthopinacoid (100) and unit-prisms (110), and sometimes the clinopinacoid (010) less pronounced. Cross-sections exhibit distinct prismatic cleavage. The form of the crystals is similar to that of ægirite. Cross-sections exhibit the emergence of an optic axis when examined in convergent polarized light. Longitudinal sections yield a maximum angle of extinction of about 35°. Hence the angle between the optic axes is about 70°. Longitudinal sections that have been cut nearly perpendicular to an optic axis exhibit the plane of the optic axes parallel to the orthopinacoid. They also exhibit a transverse parting nearly at right angles to the prism." The specific gravity of a small piece of jadeite cut as a ringstone was determined by me to be 3·27. A whole series of tests, however, made in numerous laboratories have shown that the specific gravity of jadeite is approximately 3·32. Jadeite cuts glass, its hardness being equal to that of quartz, *i.e.*, 7. The most characteristic property of jadeite is its wonderful tenacity, which everyone will have experienced who has tried to break a piece of jadeite. The reason for this extraordinary tenacity is the interwoven structure of the jadeite-needles. In order to test the strength of jadeite a series of resistance tests were made in America, and the results were published in the late Mr. Bishop's "Investigations and

Studies of Jade." The experiments were made in order to test the resistance of jadeite to impact and to compression. The following is a brief summary of the results of these tests. The material used for the experiments was jadeite from Burma having the following properties. Specific gravity 3·3122, hardness 7, colour light grey with occasional green spots, remarkably homogeneous and compact.

1. Resistance to impact.—

1	2	3	4	5
Dimensions of object used.	Direction of blow.	Number of blows to produce fracture.	Energy of final blow in centimetre grammes.	Total energy expended in centimetre grammes.
0·506 cub. inch	At right angles to cleavage.	100	100,000	5,050,000
0·504 „ „	Parallel to cleavage.	103	103,000	5 356,000
0·584 „ „	Do. do.	112	112,000	6,328,000
0·503 „ „	At right angles to cleavage.	113	131,000	8,646,000

2. Compression tests.—"The tests were made on an emery-hydraulic-testing-machine, the most accurate testing-machine known, and, in view of the interest attaching to the material, were executed with the utmost care." The material used was jadeite from Burma.

1	2	3	4	5	6	7
Dimensions of material used.	Area of material.	Maximum load in lbs.	Ultimate strength per square inch in lbs.	Total compression in inches.	Measured at load of	Percentage of compression.
1·001" × 1·013" × 1·009"	1·022 square inches.	94,450	92,416	0·027	75,000 lbs.	$\frac{48}{100}$ of 1%.
1·004" × 1·021" × 1·018"	1·039 „	79,180	76,208	...	Not measured.	...

When compared with the values given in the following table for building-stone, steel, and cast iron, the average of many tests taken

in all parts of the world, the greater tenacity of jadeite becomes very apparent:—

Sandstone	per square inch	5,000 to 15,000 lbs.
Limestone	" " "	7,000 " 20,000 "
Granite	" " "	15,000 " 35,000 "
Mild steel	" " "	40,000 " 60,000 "
Medium steel	" " "	60,000 " 80,000 "
Cast iron	" " "	60,000 " 80,000 "
Jadeite	" " "	41,000 " 95,000 "

The following tables and the remarks which follow them show the physical properties determined by measurement of the deformations produced by successive loads of 1,000 lbs. per square inch. I shall only refer to the table for Burmese jadeite.

1	2	3		4
Applied loads in lbs. per square inch.	Compressometer readings in inches.	CHANGE OF LENGTH IN INCHES.		Modulus of elasticity.
		Actual.	Difference.	
500	...	...	...	...
700	·01840	...	...	...
1,000	·01844	·00004	...	...
2,000	·01850	·00010	·00006	...
3,000	·01850	·00010	·00000	14,900,000
4,000	·01860	·00020	·00010	11,200,000
5,000	·01860	·00026	·00006	11,500,000
6,000	·01866	·00026	·00000	14,400,000
7,000	·01871	·00031	·00005	14,500,000
8,000	·01871	·00031	·00000	16,900,000
9,000	·01871	·00031	·00000	19,300,000
10,000	·01877	·00037	·00006	18,200,000
12,000	·01877	·00037	·00000	22,200,000
14,000	·01877	·00037	·00000	25,400,000
etc.	etc.	etc.	etc.	etc.

up to breaking load, when the modulus of elasticity attains the high value of 47,000,000. The most remarkable feature of these figures, and the one which shows more clearly than anything else the wonderful

tenacity and elasticity of this rare mineral, is the very high value which the modulus of elasticity attains. The extraordinary character of these figures will be understood by reference to the adjoining table, giving the approximate values of the modulus of elasticity for various well-known materials, as determined by the United States Government tests.

Steel	28,000,000	to	30,000,000
Cast iron	12,000,000	„	27,000,000
Marble	6,000,000	„	14,000,000
Blue stone	4,000,000	„	9,000,000
Granite	2,000,000	„	9,000,000
Limestone	3,000,000	„	5,000,000
Sandstone	1,000,000	„	5,000,000
Jadeite	3,000,000	„	47,000,000

The ideally pure jadeite is a silicate of sodium and aluminium, and the formula assigned to it is $NaAlSi_2O_6$. The following is an abstract from a table of analysis given in "Investigations and Studies of Jade." The material for the analysis was jadeite from Burma.

	1	2	3	4	5
Specific gravity	3·3394	3·3381	3·3373	3·3303	3·3287
Silica SiO_2	58·48	59·02	58·40	57·60	58·69
Alumina Al_2O_3	23·57	24·88	27·05	25·75	25·56
Ferric oxide Fe_2O_3	1·68	1·23	...	...	...
Magnesia MgO	1·33	1·10	·57	·13	·11
Lime CaO	1·62	1·15	·65	·58	·58
Soda Na_2O	10·33	11·21	11·37	13·31	13·09
Potash K_2O	3·09	1·34	2·20	2·20	1·54
Ferrous oxide FeO	...	·28	...	...	...
Manganese oxide MnO	...	·19	...	...	...
Loss on ignition H_2O	·16	·07	·18	·25	·17
	100·26	100·47	100·42	99·82	99·74

In order to show that ferric oxide replaces alumina and that potash, lime, and magnesia replace soda, the analyses have been modified by substituting for Fe_2O_3 an amount of Al_2O_3 equivalent to it, and for K_2O, CaO, and MgO their equivalent of Na_2O and then calculating to 100 per cent. The recalculated analysis can thus be

compared with the theoretical composition of jadeite, and it will be observed that the agreement is very satisfactory.

	1	2	3	4	5
Silica SiO_2	58·48	59·03	58·40	57·60	58·69
Alumina Al_2O_3 . . .	24·59	25·59	27·05	25·75	25·56
Soda Na_2O	16·22	15·01	14·34	15·54	14·88
	99·29	99·62	99·79	98·89	99·13

Acmite and diopside have both been identified by Penfield as isomorphously commingled with jadeite. Jadeite fuses readily before the blowpipe to a clear glass and is not decomposed by hydrochloric acid until after having been fused. In the material collected by myself inclusions of other minerals are of very rare occurrence and are restricted to a few needles of actinolite. In "Investigations and Studies of Jade" a large variety of inclusions are enumerated which are said to have been observed in jadeite. As occurring visible to the naked eye the following: chromite, magnetite, garnet, felspar, pyrites, rutile, limonite, manganese oxide, mica, and others. "In addition to these inclusions already described which are perceptible to the naked eye a large number of minerals exist in minute crystals and have been determined by microscopic study of jade itself." The following minerals have been identified by Arzruni, Iddings and others as occurring in jadeite: andalusite, cordierite, epidote, garnet, muscovite, olivine, perowskite, leucoxene, quartz, rutile, talc, titanite, tourmaline, and zircon. "The second class of inclusions, in which the foreign mineral plays a more important part in the make-up of the mass, contains the following species: analcite, albite, nephelite, plagioclase felspar, zoisite, and diopside." With reference to the last-named mineral it is important to note that albite has repeatedly been observed as occurring together with jadeite by others and myself. Albite is the only felspar which occurs together with jadeite. Nephelite and analcite have been recorded by Professor Bauer and others, although I myself did not observe it in any single instance. Diopside could not be traced in my collection of jadeite from Tawmaw, and clinozoisite never occurs as an inclusion in jadeite but frequently as a product of metamorphism in the adjacent actinolite-schists.

The first to report on the mode of occurrence of jadeite in the Kachin Hills was Dr. Noëtling. An interesting description of the

mines as they were 15 years ago will be found in the Records of the Geol. Survey of India, Vol. XXVI, Part 1. A general survey of the jade-mines gives one the impression that the jadeite occurs as a broad dyke in the serpentine. The strike of this dyke is N. to S., and the dip averages 60°. In my opinion an outcrop of white jadeite set off against the dark green of the serpentine must have led to the discovery of the jadeite at Tawmaw. The nature of the dyke is illustrated in fig. 3. It will be observed that on the hanging wall the serpentine is separated from the dyke proper by a broad layer of earthy chlorite. Beneath the chlorite lies the albite rock containing inclusions of schistose amphibolite. This gradually passes over into a mixture of jadeite and albite beyond which comes the pure jadeite. On the foot-wall the jadeite-albite rock is bounded by amphibolite, the latter imperceptibly passing into serpentine. The microscope showed that the earthy chlorite rock consists of the following minerals: chlorite, actinolite, clinozoisite, biotite, and chloritoid. Several specimens of dark green banded jadeite were taken from near the foot-wall. This jadeite encloses numerous parallel thin layers of actinolite schist.

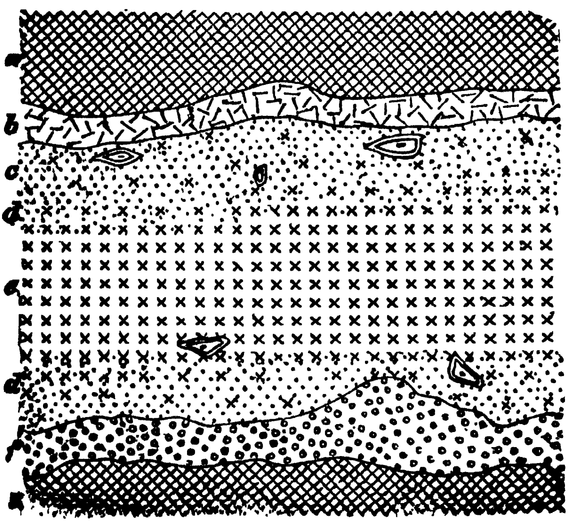

Fig. 3.

Section through the jadeite-albite dyke at Tawmaw.

a. Serpentine. *b.* Earthy chlorite. *c.* Albite rock with inclusions of schistose amphibolite. *d.* Zone of mixed albite and jadeite. *e.* Jadeite. *f.* Amphibolite.

It is necessary once more to impress the fact upon all readers that the dyke is not solely composed of jadeite, but that albite is also an important constituent mineral here. It has been stated previously that in many instances it becomes extremely difficult to distinguish the jadeite from albite. Obviously the jadeite-albite dyke as seen in fig. 3 was produced by a process of differentiation in the molten magma during its solidification. The portions rich in soda, as represented by the albite, concentrated towards the outer margins, whereas the less acid metasilicate jadeite was concentrated in the centre of the dyke. Strictly speaking this is not quite correct, as will be shown in the sequel.

The genesis of jadeite has long been a problem of considerable interest. The problem is one of exceptional petrographical difficulty and certainly cannot be solved on the basis of incomplete and chance observations in a laboratory. This has repeatedly been attempted, and it is therefore not surprising that numerous conflicting statements on the genesis of jadeite have been made. Professor Bauer classed the jadeite with the group of "crystalline schists." Dr. Noetling considers the jadeite to be an eruptive dyke intrusive into serpentine and of tertiary age. E. Weinschenk and Sir T. H. Holland regard jadeite as a primary segregation from the serpentine magma. H. Rosenbusch, who also classes jadeite with the "crystalline schists," points out that in its chemical composition jadeite is closely related to elæolite-syenite, the absence in jadeite of potash being practically the only difference. Potash, however, can replace up to 4 per cent. of soda, as has previously been shown, so that Rosenbush's remark on the absence of potash does not appear quite justified. The following theory on the origin of jadeite has been suggested in the late Mr. Bishop's "Investigations and Studies of Jade:" "Jadeite is a metamorphosed igneous rock, a member of the phonolite family. The whiter varieties are probably metamorphosed dykes of the aplitic leucocratic type belonging in this family and the darker green types those containing more iron-bearing dark silicates like the tinguaites." In the following remarks I shall develop my own theories on the origin of jadeite, based on careful studies in the field and in the laboratory. There cannot be the slightest doubt that the jadeite-albite dyke at Tawmaw is of igneous origin and intrusive into serpentine. In this it will be seen my opinion agrees with that expressed by Dr. Noetling. It was repeatedly observed that small veins of jadeite-albite had penetrated into the country rock showing how

the molten magma was forced into the serpentine. Furthermore numerous angular and schistose inclusions of serpentine and amphibolite prove the intrusive nature of the dyke. There are also undoubted signs of contact metamorphism produced by the intrusive jadeite-albite on the serpentine, the most conspicuous phenomenon being the development of new minerals such as chlorite, clinozoisite, tawmawite, chloritoid, and soda-amphibole. These minerals are restricted to a narrow zone of metamorphosed serpentine on both foot and hanging-walls of the dyke. The production of soda-amphibole is of especial interest, as it shows that both the serpentine and the jadeite-albite contributed their share to its development. Within the zone of contact the jadeite-albite rock often assumes a banded and schistose character on account of the numerous parallel inclusions of amphibolite.

The classificatory position of the jadeite-albite amongst the igneous rocks must next be established. Following Rosenbush's suggestion the following analyses have been selected for comparison. No. 1 is the analysis of a jadeite-albite rock from Tawmaw made by Foot (Investigations and Studies of Jade). No. 1*a* is an analysis of typical jadeite. No. 1*b* the analysis of albite from Tawmaw. No. 2 is an analysis of nephelite-rhomb-porphyry from Vasvik in Norway. No. 3 an analysis of elælolite-porphyry from Predazzo in the Tirol. No. 4 an analysis of soelvsbergite from the Crazy Mountains, Montana, U. S. A. (Numbers 2, 3 and 4 are taken from Rosenbusch, Grundzüge der Gesteinslehre).

	1	1*a*	1*b*	2	3	4
Silica SiO_2 . .	58·58	58·48	67·10	56·04	57·20	58·70
Alumina Al_2O_3 . .	23·71	23·57	20·42	22·15	20·04	19·26
Ferric oxide Fe_2O_3 .	0·51	1·68	0·23	1·06	2·90	3·37
Ferrous oxide FeO .	0·24	...	...	3·28	1·20	0·58
Magnesia MgO .	1·35	1·33	...	1·12	0·40	0·76
Lime CaO . . .	1·63	1·62	...	2·42	3·19	1·41
Soda Na_2O . .	...	10·33	8·93	8·39	7·85	8·55
Potash K_2O . . .	13·80	3·09	3·20	5·03	4·12	4·53
Loss on ignition H_2O .	0·30	0·16	...	0·67	2·20	2·57

No. 1 is an analysis of a typical albite-jadeite rock. The microstructure is described as follows: "A comparatively coarse grained aggregate of jadeite crystals, the larger of which are 0·6 millimetres in diameter. The rock is colourless in thin sections with small spots of clouded material. It is almost wholly jadeite, the clouded matter being indeterminable and presumably the beginning of decomposition. The grains or anhedrons of jadeite are irregular and of various sizes. In some cases the prismatic cleavage is distinct. In places there are patches of colourless mineral with a lower index of refraction than that of jadeite and with the double refraction and polysynthetic twinning of plagioclase felspar. It acts as a matrix in which small prisms of jadeite lie in all positions and against which the jadeite is automorphic. It exhibits no sign of alteration whether of decomposition or of crushing."

A comparison of the analyses given above shows how very similar in chemical composition jadeite alone as well as the jadeite-albite rock is to rocks of the elæolite-syenite group. This, however, does not imply that the jadeite-albite may actually be regarded as belonging to that group of rocks. It is impossible to conceive that only one dyke of a certain type of igneous rock exists without there being signs of either large intrusive masses of the same rock in the vicinity or at least other similar dykes. Neither elæolite-syenite nor any other rocks of this type exist in the jade-mines district.

Another theory based on the principles of differentiation offers a more satisfactory explanation. According to this the jadeite is a product of differentiation within a peridotite magma. Before discussing this theory it is necessary to point out that the serpentine is of true igneous origin. In all probability it is a dunite in an advanced stage of serpentinisation. The surrounding "crystalline-schists" represent original sheets of basic igneous rocks altered by metamorphism in contact with granite. Within the magma reservoir from which all these rocks originated a differentiation took place previous to the eruptions of either peridotite or jadeite-albite. The more basic peridotite magma being the more readily separable was erupted first, leaving that more acid jadeite-albite rock to be discharged later. The latter was then forced into a fissure of the already solidified peridotite. This, however, does not explain the extraordinary mineral paragenesis of jadeite and albite. It is conceivable that a magma can differentiate into two portions, the one representing peridotite and the other

closely resembling a nephelite-syenite in chemical composition. If normally developed the mineral constituents of the latter rock should be alkali felspar, nephelite, ægirite, and soda amphiboles. The absence of these minerals as important constituents of the dyke-rock intimate that abnormal conditions must have prevailed during the solidification of the magma. Jadeite is, as has been pointed out, a mineral of high specific gravity. Minerals of high specific gravity suggest development under high compression due to orographic movements during the solidification of the rock. As a result of high pressure a rock which under normal conditions would crystallize with the mineral paragenesis of albite-nephelite, etc., will develop the anomalous paragenesis of albite and jadeite. We may therefore assume that an intrusive dyke of mineral matter rich in soda can lead to the primary formation of an albite-jadeite rock when solidifying under anomalous conditions (*i.e.*, piezocrystallization).

In the following an attempt will be made to prove that the jadeite is of metamorphic origin. Metamorphism, though affecting the mineral composition, would not necessarily alter the chemical composition. The best criterion as to whether a rock has been metamorphosed or not is undoubtedly its internal structure. In this case, however, the microscope gives very unsatisfactory results, as every specimen examined is so highly cataclastic that the original structure is totally unrecognisable. It therefore became necessary to attack this problem from a different point of view. As has already been explained, nephelite and albite should be expected as minerals resulting from a normal solidification of a magma rich in soda. Presuming that this mineral paragenesis originally existed in the dyke-rock and that a process of metamorphism produced the jadeite without altering the chemical composition, then it becomes obvious that the jadeite was developed at the expense of nephelite which has almost completely disappeared. This is by no means an impossibility, as the following calculations illustrate. Nephelite is the monosilicate of aluminium and sodium $NaAlSiO_4$, albite the polysilicate $NaAlSi_3O_8$. Now one molecule of nephelite plus one of albite $=$ 2 $NaAl\ Si_2O_6$ *i.e.*, two of jadeite. The correctness of these simple calculations is proved by referring to the chemical analyses of the minerals in question. The following is a series of analyses of albite and nephelite especially selected for the purpose of showing how any combination of $\frac{1}{2}$ albite and nephelite

gives one of jadeite. No. I*n*, II*n*, and III*n* are analyses of nephelite, I*a* II*a*, and III*a* analyses of albite.

	Nephelite analyses.			Albite analyses.		
	I*n*.	II*n*.	III*n*.	I*a*.	II*a*.	III*a*.
SiO_2	44·08	43·74	44·98	67·10	68·28	69·69
Al_2O_3	33·28	34·48	34·49	20·42	19·62	18·60
Fe_2O_3	...	..	...	·23	...	...
MgO	...	.	...	...	·09	·20
CaO	1·85	...	·50	...	·31	...
Na_2O	16·00	16·62	15·49	8·93	10·81	10·28
K_2O	4·76	4·55	4·68	3·20	·39	·40
	99·97	99·39	100·14	99·88	99·50	99·17

		$\frac{In}{2} + \frac{Ia}{2}$ = jadeite.	$\frac{IIn}{2} + \frac{IIa}{2}$ = jadeite.
Silica	SiO_2 . . .	22·04 + 33·55 = 55·59	21·87 + 34·14 = 56·01
Alumina	Al_2O_3 . . .	16·64 + 10·21 = 26·85	17·24 + 9·81 = 27·05
Ferric oxide	Fe_2O_3 . . .	... + ·11 = ·11	... + ... = ...
Magnesia	MgO . . .	... + ... = ...	.. + ·04 = ·04
Lime	CaO . . .	·92 + ... = ·92	... + ·15 = ·15
Soda	Na_2O . . .	8·00 + 4·46 = 12·46	8·31 + 5·40 = 13·71
Potash	K_2O . . .	2·38 + 1·60 = 3·98	2·27 + ·19 = 2·46
		99·91	99·42

		$\frac{In}{2} + \frac{IIIa}{2}$ = jadeite.	$\frac{IIn}{2} + \frac{IIa}{2}$ = jadeite.
Silica	SiO_2 . . .	22·04 + 33·55 = 55·59	21·87 + 34·14 = 56·01
Alumina	Al_2O_3 . . .	16·64 + 10·21 = 26·85	17·24 + 9·81 = 27·05
Ferric oxide	Fe_2O_3 . . .	... + ·11 = ·11	... + ... = ...
Magnesia	MgO . . .	... + ... = ...	... + ·04 = ·04
Lime	CaO . . .	·92 + ... = ·92	... + ·15 = ·15
Soda	Na_2O . . .	8·00 + 4·46 = 12·46	8·31 + 5·40 = 13·71
Potash	K_2O . . .	2·38 + 1·60 = 3·98	2·27 + ·19 = 2·46
		99·91	99·42

		$\frac{In}{2} + \frac{IIa}{2}$ = jadeite.	$\frac{IIIn}{2} + \frac{IIa}{2}$ = jadeite.
Silica	SiO_2	22·04 + 34·14 = 56·18	22·49 + 34·14 = 56·63
Alumina	Al_2O_3	16·64 + 9·81 = 26·45	17·24 + 9·81 = 27·05
Ferric oxide	Fe_2O_3	... + ... = ...	... + ... = ...
Magnesia	MgO	... + ·04 = ·04	... + ·04 = ·04
Lime	CaO	·92 + ·15 = 1·07	·25 + ·15 = ·40
Soda	Na_2O	8·00 + 5·40 = 13·40	7·74 + 5·40 = 13·14
Potash	K_2O	2·38 + ·19 = 2·57	2·31 + ·19 = 2·50
		99·71	99·76

(Analyses I*n* and III*n* by Rammelsberg and Rauff, II*n*, II*a*, and III*a* Rosenbusch, Elemente der Gesteinslehre; I*a*, analysis of albite from Tawmaw). On comparing the jadeite analyses on page 274 with the jadeite resulting from the combination of ½ albite *plus* ½ nephelite in the above tables it will be observed that the likeness is practically perfect.

It is conceivable that the jadeite-albite dyke at Tawmaw originally solidified under normal conditions as a nephelite-albite rock. As neither albite nor nephelite possesses heteromorphic eqiuvalents which could crystallize under anomalous conditions, metamorphism cannot alter either of these two minerals individually and independently of each other. For the combination of one part albite and one part nephelite, however, the heteromorphic equivalent is jadeite, as has been shown above. Metamorphism acting under very high pressure can therefore be held responsible for the development of jadeite.

The presence of nephelite in jadeite has been repeatedly recorded (Investigations and studies of Jade). Professor Bauer has also observed nephelite in jadeite and calls attention to the anomaly of the presence of nephelite as a compound of a rock belonging to the crystalline schists, since heretofore it has been found only as a component of igneous rocks. Bauer maintains that the nephelite bearing jadeite occurs in Tibet. It is, however, very doubtful whether an occurrence of jadeite exists in Tibet. [The only localities in Asia actually known to produce jadeite are Karakash in Turkestan and the three places in the Kachin Hills—Tawmaw, Hwéka and Mamon. I am convinced

that the so-called Tibetan jadeite comes from Burma, *i.e.*, from Tawmaw. Burmese jadeite, which is smuggled across the frontier to avoid payment of royalty, is very probably identical with the so-called Tibetan jadeite.] The fact that nephelite as well as analcite have thus been identified as occurring together with jadeite constitutes a very valuable proof in favour of our theory of the metamorphic origin of jadeite. It must be added that in places where albite was preponderant over nephelite the metamorphism must have produced an albite-jadeite rock, and wherever nephelite outweighed the albite the result was a jadeite-nephelite rock.

Another phenomenon which can also be satisfactorily explained by our theory of metamorphism is the occurrence of green spots in the pure white jadeite. There is no reason to suppose that the chromite and magnetite would, during the process of differentiation within the magma reservoir, have been totally absorbed by the peridotite-magma. A certain amount will have remained with the other portion of the magma and thus have crystallized as chromite and magnetite in the nephelite-albite rock. During the process of metamorphism the chromite and magnetite were destroyed, the oxides both of chromium as well as of iron entering into the constitution of jadeite. Thus the green spots in the white jadeite mark the place where chromite and magnetite occurred in the original albite-nephelite rock.

It remains to be explained what species of metamorphism is responsible for the production of jadeite. Granite was traced in the immediate neighbourhood of Tawmaw traversing the basic eruptive rocks, *i.e.*, the "crystalline schists" in all directions. In all probability, therefore, the nephelite-albite rock was affected by the same intrusion of granite and metamorphosed to a jadeite-albite rock. To the powers of contact metamorphism were added those of abnormal pressure due to orographic movements during the consolidation of the rock.

Genetic connections undoubtedly exist between the jadeite-albite and the "crystalline-schists." These rocks have two points in common. They are distinguished by their relatively high percentage of soda and chromium. Evidently the whole series of rocks, "crystalline-schists," jadeite-albite, serpentine, and granite constitute a petrographical province. The sequence of eruptions was as follows. The earliest eruptions were strongly basic. The central mass of this

basic magma solidified as peridotite, the outer belt as gabbro. These eruptions were followed by the intrusion of the nephelite-albite magma. The most acid portion of the whole mass, the granite, represents, as is generally the case, the last phase of eruptivity.

As regards the serpentine round Kansi and that west of Hwéka, they are undoubtedly of the same origin and age as that of Tawmaw. In any case the serpentine is considerably older than the Tertiary strata which set in east of Lonkin. The cataclastic structure observed in all these rocks can only be explained as resulting from tectonic disturbances in later geological periods.

From the petrologist's point of view the jadeite occurrence at Tawmaw is beyond doubt the most interesting. As regards the jadeite diggings at Mamon the only question of interest is whence the material, which is found in the shape of boulders in the river gravel, originates. A glance at the accompanying geological map (Pl. 39) shows that the portion of the course of the Uru chaung, bearing jadeite boulders, surrounds the hills of Tawmaw, beginning at Sanka and reaching round as far as Mamon. The numerous little streams feeding the Uru from the right bank also carry boulders of jadeite. It is therefore highly probable that the boulder jadeite found in the valley of the Uru has originated from the jadeite-albite dyke which is now being worked at Tawmaw, the more so as all the other species of rock occurring together with the jadeite at Tawmaw are also found amongst the boulders in the bed of the Uru chaung. The inference to be drawn from these observations is that it is highly improbable that jadeite will be found in sufficient quantity for remunerative working far beyond Mamon or north of Sanka.

Another problem of interest is whether the jadeite found at Hwéka is in any way connected with that of Tawmaw. Jadeite, saussurite, serpentine, etc., occur in the shape of boulders as constituents of a miocene conglomerate. Obviously the Tertiary strata were deposited round the serpentine hills and derived the material of which they are composed from the same. Although in all probability the boulder-jadeite actually originates from Tawmaw this cannot be proved conclusively, and another unknown primary occurrence of jadeite may exist in the vicinity, which furnished the material for the secondary deposit at Hwéka.

LIST OF PLATES.

THE WETCHOK-YEDWET PEGU OUTCROP, MAGWE DISTRICT, UPPER BURMA. BY E. H. PASCOE, M.A., B.SC., F.G.S., *Geological Survey of India.* (With Plates 40 to 42.)

Position of area.

THIS area was examined in April 1907, and surrounds Yedwet (Latitude 20° 25′ 54″; Longitude 95° 16′ 21″), a village 23 miles almost due east of the town of Yenangyaung.

Neighbouring country.

The intervening country between it and the town of Magwe consists of a gently undulating plain, that part of it bordering the Irrawadi being comparatively little dissected by streams. The rocks are Pliocene[1] sands covered in most places by a surface deposit which is usually of a brick red colour, but occasionally assumes that of a dull chocolate or bright vermilion. Near the river patches of gravel take the place of or accompany this deposit, and are evidently but local variations of the latter. The red deposit may occur on high, and be absent on low ground, or *vice versâ*, and has apparently been laid down upon an irregular surface of Pliocene here.

Geological structure.

The structure is that of an elliptical dome with its major axis running in the usual direction of Miocene or Pegu anticlines in Burma, *i.e.*, N. N. W. to S. S. E. Judging from the strike of the Pegu-Irrawadi boundary bed, the trend of this anticline is from 20° W. of N. to 20° E. of S. (see map, Plate 42). Minor wrinkles are probably indicated by irregular dips.

The maximum width of the Pegu outcrop is a little over 4½ miles; its total length was not measured. The western Pegu-Irrawadi boundary bed when followed southwards curves in towards the east so that the Pegu outcrop evidently does not extend further than about 4 miles south of Padaukkon. Northwards the writer found Pegu beds at least as far as the village of Okshitkon, ¾ mile north of which Mr. Macrorie, Geologist to the Burma Oil Company, reports

[1] Irrawadi Sandstone series.

having found the conglomerate boundary bed. The length of the outcrop must therefore be about 14½ miles.

Dips.

Dips are very gentle, especially around Yedwet and the Setkyadaung Hills, where they are very irregular in direction and seldom rise above 6°. On the eastern and western flanks of the fold, dips rise to 10°, 15°, or occasionally 18° or 20°. North of Yedwet, northerly dips of 15° and over extend for some distance northwards and are rather difficult to account for except by the assumption of a well-marked unconformity, or faulting in an east and west direction, especially since there are no correspondingly large southerly dips south of Yongon in spite of the closer proximity of the Irrawadi Sandstone boundary. North of the road between Wetchok and Thamonbin, the dips all have a northerly component with the exception of a few local irregularities. In the area immediately south of Yedwet, and from the centre of the Setkyadaung Hills to the stream which passes between Myintha and Yongon, dips may be considered as superficial or due to minor bulging, and the strata as generally horizontal. It would be impossible to mark the position of any crest, but since there is little inequality between the dips on the eastern and western flanks, the crestal area would occupy a central position between the eastern and western margins. Plate 41 gives a general idea of the anticlinal dome seen in the direction of the major axis: both flanks of the fold are shown.

A curious case of local crumpling and unconformity in the Pegu beds is to be seen in the Yedwet Chaung (see Plate 40), where contorted clays and sandstones are abruptly truncated and overlain by horizontal beds: the phenomenon is quite local.

Age and nature of beds.

The rocks exposed are undoubtedly Pegu beds, and are mostly of the customary type. The predominant characteristic, as usual, is impurity, the sandstones are argillaceous, and the clays and limestones sandy. It is difficult sometimes to decide whether a bed should be called a calcareous sandstone or an arenaceous limestone. Each fossil band met with consists of such a variable non-descript bed, weathering like a limestone, but sometimes containing a larger percentage of sand and pebbles of clay than of calcium carbonate. The clay pebbles are occasionally riddled with *Lithodomus* borings, and the sand consists largely of felspar, a small proportion of which is plagioclase, the bulk being orthoclase. The remaining constituents of the rock are shells

and shell-fragments, Bryozoa, Foraminifera, and iron oxide. Fossil bands are sometimes very limited in horizontal extent, occurring in patches here and there. These isolated outcrops frequently correspond to identical horizons, but their thinness and the curved or mammillated nature of their bounding surfaces confirm the probability that they have been formed by the introduction of calcareous matter into a porous fossiliferous sand. The unfossiliferous limestones are usually much purer and possess a more markedly mammillated or even botryoidal form. It is very questionable whether any limestones other than secondary exist in this area.

A very common type of bed here and in Pegu exposures elsewhere is that of a soft light-coloured sand containing numerous laminæ or elongated lenticels of a bluish or greenish clay, presenting from a suitable distance the appearance of shale. Exactly similar beds are being formed at the present day in the sand-banks of the Irrawadi, where thin sheets of clay crack and curl up into hundreds of isolated patches which are smoothed down and covered with sand subsequently to form separated lenticels.

Two other interesting types of bed from the Pegu series are worthy of notice. One is an arenaceous limestone occurring very close to the Pegu-Irrawadi boundary. It contains a large proportion of sand consisting mostly of quartz in large moderately rounded grains, a little orthoclase and plagioclase, and some green pleochroic hornblende. The rock is stained with thin brown concentric spheroidal shells of iron and manganese oxide, which weather more readily than the rest of the rock, and produce a surface ornamented with mutually interfering systems of concentric rings, the whole structure forcibly imitating the "orbicular" structure in that form of diorite known as "corsite" or "napoleonite."

The other type is a fine-textured brown calcareous clay showing well-developed cone-in-cone structure, occurring here and there a short distance below the junction of Pegu with Irrawadi beds. In the small quantity of material brought back from the field, all the cones point in one direction and their curved surfaces where exposed exhibit the remarkable system of transverse wavy ridges and wrinkles, characteristic of this structure.

Selenite is abundant locally, and calcite occurs in the tributary stream-beds immediately north of Yedwet village. Deep blue clay similar to that which is the most prominent feature of Noetling's

"Prome Stage" can be observed near Chaungzon and at Okshitkon: this similarity has evidently no correlative significance.

The lowest bed of the Irrawadi series, which has been referred to above as the 'boundary bed,' varies in nature from place to place, but is usually a highly arenaceous limestone or a calcareous sandstone. The particles of sand are very coarse and frequently assume the size of small pebbles of 3 or 4 mm. diameter. The larger ones consist of quartz, but orthoclase and plagioclase are present, the former sometimes in abundance. The matrix of calcite is stained with ferric oxide, and varies in amount, but the rock always weathers like a limestone. In places, as near Magyigon, this bed is associated with or passes horizontally into a ferruginous calcareous conglomerate containing clay pebbles thickly coated with iron oxide and occasional pieces of fossil wood, thus strongly resembling the Ferruginous Conglomerate of Yenangyaung and other places, to which it doubtlessly corresponds.

Thickness of Pegu beds exposed.

The Setkyadaung Hills are covered with large water-worn boulders of this 'boundary bed,' so that the thickness of Pegu beds exposed must be very small. According to the contours of the 1-inch Government survey map, the height of Setkyadaung on which Irrawadi boulders occur, above the Chaung immediately south of Yedwet, is about 280 feet, so that the thickness of Pegu rocks exposed here may be considered as approximately 300 feet.

Fossils.

Fossils are fairly plentiful, but very fragmentary, and occur in the thin slabs and flattened spheroidal masses of hard sandy limestone described above, from which they are very difficult to extract.

The lowest fossil bed is found immediately around Yedwet. It is characterised by a profusion of large *Turritellæ* belonging to the two species *simplex* and *acuticarinata*. These two distinct species are closely related to one another and intermediate forms are frequently met with, in which the older whorls with the single sharp keel of *simplex* are succeeded by younger whorls with the double keel of *acuticarinata*: *Turritella simplex* is evidently the ancestor of *Turritella acuticarinata*. Large specimens of *Conus avaënsis* and intermediate forms between this and *Conus malaccanus* are also common. Both *Turritellæ* and the *Conus* can be found loose in the stream beds, weathered out from the parent rock. Perhaps the most interesting occurrence in this and neighbouring horizons is that of a foraminifer,

which appears to be a variety of *Rotalia annectens* Parker and Jones,[1] an inhabitant at the present day of the "anchor mud" of Hongkong and the coral reefs of Fiji. Both forms show the same distance between consecutive septa, the same conus-shape, and the same angular projecting processes from the septa, the only slight difference being that in the Yedwet specimens these processes are situated a little closer to the axis of the spire. Besides this, doubtful specimens of *Globigerina* and of a Textularian were observed.

The following is a list of species obtained from this bed, but by far the greater portion of specimens consist of *Turritellæ*. (*N.B.*—Those marked with an asterisk are common.)

Rotalia annectens Parker and Jones.
Globigerina ?
a Textularian ?
Ostrea promensis Noetl.
Ostrea papyracea Noetl.
Pecten kokenianus Noetl.
Cardita visquesneli d'Arch.
Dione protophilippinarum Noetl.
Dentalium junghuhni K. Martin.
* *Turritella simplex* Jenkins.
* *Turritella acuticarinata* Dunker.
Oliva rufula Duclos.
Clavatula munga Noetl.
* *Conus avaënsis* (varieties resembling *C. malaccanus*) Noetl.
* *Balanus tintinnabulum* Linné.

The uppermost fossiliferous horizon varies considerably from place to place and occurs close to the boundary. Just east of Wetchok numerous crab claws were obtained, mostly consisting of the dactylopodite and occasionally the propodite of the chelate limb. A *Placenta*, identical with the living *Placenta orbicularis* which Mr. Tipper found in the Miocene of the Andaman Islands, also occurs. The following is a list of species found here :—

Ceratotrochus alcocki ? Noetl.
Dendroid coral—probably *Dendrophyllia* sp.
Ostrea papyracea Noetl.

[1] *Phil. Trans.*, Vol. 155, 1865, p. 422, and Pl. XIX, fig. 11.

Pecten kokenianus Noetl.
Placenta orbicularis Gray.
Lithodomus.
Cardita visquesneli d'Arch.
Dione protophilippinarum Noetl.
Tellina hilli Noetl.
Gari kingi Noetl.
Dentalium.
Turcica protomonilifera Noetl.
Natica obscura Sow.
„ *callosa* Sow.
Conus avaënsis Noetl.
„ *malaccanus* Hwass.
Balanus tintinnabulum Linné.
* *Cancer* (claws) sp. (figures in Noetling's "Fauna of the Miocene Beds of Burma.")[1]
Oxyrhina spalanzani Bon.
Chelonian plate.
Calliostoma blanfordi Noetl.

Near Thamonbin this bed consists of an oyster bank of *Ostrea promensis* and contains in places specimens of *Twingonia.*[2]

Paracyathus cæruleus Duncan.
Pecten kokenianus Noetl.
Cardita visquesneli d'Arch.
Dione protophilippinarum Noetl.
Balanus tintinnabulum Linné.

From the same horizon in the stream-bed immediately north of Padaukkon the following were obtained :—

Paracyathus cæruleus? Duncan.
Pecten kokenianus Noetl.
Pecten irravadicus Noetl.
Arca.
Gari kingi Noetl.
Dentalium junghuhni K. Martin.
Solarium maximum Phillipi.
Mitra sp.

[1] *Palæont. Ind.*, New Ser., Vol. I, p. 3, Pl. XXIV.
[2] See *Rec. Geol. Surv. Ind.*, Vol. XXXVI, Part 3, p. 138.

Cypræa granti d'Arch.
Conus hansa Noetl.
„ *yuleiensis* Noetl.

Other fossil limestones occur, whose horizontal extent is probably small. Fossils are frequently very fragmentary, and, except for specimens of *Strioterebrum*, *Cidaris* sp., *Turritella lydekkeri*, and a tooth of *Carcharias*, consist of species included in the two lists given above.

Age of beds.

It is doubtful how far fossil beds in a new locality can be compared with zones claimed to have been established by Dr. Noetling at Singu, Yenangyat, Minbu, Thayetmyo, Prome, etc. A glance at the three dissimilar lists of fossils from the Wetchok, Thamonbin, and Padaukkon beds, whose horizons are either identical or within a few feet of each other, will show what a difficult task it is to correlate Pegu beds even in the same area. The following table shows the number of species from the two horizons described, common to each of Dr. Noetling's zones, assuming the Wetchok, Thamonbin, and Padaukkon beds to represent one horizon:—

	Zone of *Cytherea erycina*.	Zone of *Aricia humerosa*.	Zone of *Pholas orientalis*.	Zone of *Parallelipipedum prototortuosum*.	Zone of *Arca theobaldi*.	Zone of *Anoplotherium birmanicum*.	Zone of *Paracyathus cæruleus*.	Zone of *Cancellaria martiniana*.	Zone of *Dione dubiosa*.	Zone of *Meiocardia metavulgaris*.	Zone of *Mytilus nicobaricus*.	Zone of *Cardita tjidamarensis*.	Zone of *Cyrena crawfurdi*.	Uncertain.
Lower or Yedwet bed.	4	6	3	11	8	2	3	3	0	4	6	0	0	1
Upper or Wetchok, Thamonbin, Padaukkon bed.	7	9	5	15	11	4	14	14	0	13	11	0	0	1

Correspondence with the two fossil horizons established in the Yenangyaung Oil-field[1] is just as ill.

The Irrawadi or Pliocene series is represented by the usual light coloured coarse current-bedded sand rock with local iron-staining and much fossil wood. Of the latter a Monocotyledonous variety belonging or related to the Palms was found close to the 'boundary bed' west of Myintha. The characteristic obliquity of the cauline vascular bundles to the stem axis where the former are about to enter a leaf is well seen. In some specimens the bundles have been destroyed and replaced by oxide of iron, in others their structure has survived, and each is seen to be of cordiform section with the sinus directed towards the stem centre.

Surface deposits.

The highest ground in this area, the Setkyadaung Hills, is covered with thin patches of the bright red earth alluded to above, and a red deposit very similar to this but exhibiting more the habit of an alluvial silt, occurs thickly on lower ground and in the valleys. The explanation seems to be that the high-lying red earth which is usually of a considerably brighter colour, is a soil deposit of a lateritic nature, analogous to the "Red Earth" of Bermuda or the "Terra Rossa" of south-eastern Europe, while the lower-lying bed has been derived from this by the action of rain or rivers. On the summits and down the slopes of many of the hills lie numerous large boulders of sandy limestone well rounded and carved into the characteristic alternation of concave and convex surfaces of water action: many of these boulders are apparently *in situ*. We are therefore justified in assuming that the country around Yedwet must have been recently flooded, the low-lying red deposit probably being one of the results. Unfortunately it is frequently impossible to distinguish definitely between the red lateritic soil and the redistributed material, nor is it certain how much of the low lying deposit in other areas may not be mere rain-wash. Whether the bright vermilion colour is to be taken as an exclusive feature of the lateritic or high lying type is a point worthy of the observation of future observers. Although the deposition of the alluvial material was unquestionably prior to the details of the present drainage system, it is evident that the relative positions of high and low ground before the deposition of the silt were broadly similar to what they are at the present day. In several cliff sections, red silt often

[1] *Rec. Geol. Surv. Ind.*, Vol. XXXVI, Part 3, pp. 136, 140.

30 or 40 feet thick is seen to rest upon two or three feet of an irregular band of coarse stream detritus consisting of pebbles and rounded or subangular boulders of limestone. The character of this alluvial silt is constant over wide areas. In this region, at Magwe, in the Yenangyaung Oil-field, on the Minbu hills, and elsewhere it consists of a mixture of clay and fine sand in varying proportions, deeply stained with iron oxide. Occasionally it assumes a brown and purple colour, but it is usually a brick red. No organic remains have ever been found, and there are no bedding planes. Small strings or patches of gravel or gravelly sand relieve the monotony here and there, especially in the vicinity of any conglomeratic Tertiary bed. In the opinion of the writer, the Red Silt is homotaxial with the Plateau Gravel of Dr. Noetling[1] since both deposits occupy a more or less identical horizon, and at Yenangyaung the two can be traced laterally into one other.

Faults.

The presence of the red surface deposits makes it extremely difficult to find and trace faults, and some of them may be entirely hidden from view. By a good deal of interpolation, however, the faults indicated on the map were made out with tolerable certainty.

Prospects of obtaining oil.

No oil seepages occur. Information was sent by villagers to the Twinzas at Yenangyaung that gas had been seen rising from the summit of a hill near Wetchok, but this was nothing but hot air convection currents.

According to the evidence at Yenangyaung, the effect of small faults upon an oil-field is negligible, so that practically the only risk to be run in exploiting this dome is that it may lie beyond the oil belt or zone. The structure is eminently suitable for the accumulation of oil, but the chances appear to be very even and can only be gauged by a practical test. Water is very scarce, and it is doubtful whether sufficient for boiler use would be forthcoming locally during the dry months.

[1] Mem. Geol. Surv. Ind., Vol. XXVII, Part 2, p. 55.

NOTE ON A GROUP OF MANGANATES, COMPRISING HOLLANDITE, PSILOMELANE, AND CORONADITE. BY L. LEIGH FERMOR, A.R.S.M., B.SC., F.G.S., *Assistant Superintendent, Geological Survey of India.*

IN a paper entitled 'Manganese in India' read before the Mining and Geological Institute of India in March, 1906, and published in August of the same year,[1] I proposed the name *hollandite* for an crystalline mineral found in the Kájlidongri manganese mine, in Jhábua State, Central India, and shown by analysis to have the composition of a complex manganate corresponding to the hypothetical acid H_4MnO_5. The analysis made by Mr. Winch corresponds to the formula:—

$$m(Ba,Mn)_2MnO_5 + n(Fe,Al)_4\ (MnO_5)_3$$
$$\text{or } m(Ba,Mn)_2MnO_5 + nFe_4(MnO_5)_3,$$

According as the alumina shown in the analysis be considered as an essential constituent or not.

Similar crystalline manganates have since been found in several other manganese-ore deposits, though usually mixed with other ores of manganese, such as psilomelane and braunite. These other localities are all in the Central Provinces, and the only one of them in which the manganate occurs in large individuals that can easily be separated from the associated minerals is Sitapár in the Chhindwára district, from which deposit some thousands of tons of sparkling crystalline hollandite have been shipped.

Laspeyres[2] has already suggested that *psilomelane* may conform to this formula, H_4MnO_5, and I find that all the complete analyses of psilomelane that I have had made agree very closely with this supposition.

In a paper published in the *American Journal of Science* in 1904[3] Messrs. W. Lindgren and W. F. Hillebrand describe a

[1] *Trans. Min. Geol. Inst, Ind.*, I, pp. 76, 77 (1906).

[2] Dana's System of Mineralogy, p. 2571, 6th Edition; *Jour. fur. prak Chemie.* XIII, p. 215, (1876) [quoted by Dana].

[3] Series iv, XVIII, pp. 448-451. Also see 'The Copper Deposits of the Clifton-Morenci District, Arizona', by W. Lindgren; Professional Paper No. 43 of the United States Geological Survey, pp. 103-105 (1905).

new mineral *coronadite*, from the Clifton-Morenci copper area of Arizona, United States of America. The mineral, which was found intimately mixed with quartz on a dump of the Coronado vein, is described as being black and metallic, and not unlike psilomelane in appearance. The structure is finely fibrous, the hardness about 4, and the streak black with a brown tinge. The analysis of a specimen having a specific gravity of 5·246 is given as follows :—

MnO_2	56·13
MnO	6·56
PbO	26·48
ZnO	0·10
CuO	0·05
MoO_3	0·34
Al_2O_3 (with a little TiO_2, P_2O_5, and V_2O_5)	0·63
Fe_2O_3	1·01
H_2O	1·03
Insol. and SiO_2	7·22
CaO, MgO, alkalies and loss	0·45
	100·00

In discussing the formula corresponding to the foregoing analysis, Dr. Hillebrand remarks that if the mineral is to be regarded as anhydrous the comparatively simple formula $R''(Mn_3O_7)''$ satisfies the analysis. He says, however, that the temperature at which the water is expelled indicates that it is constitutional, and that in this case the formula becomes much more complex, namely, $R''_4H_2(Mn_{12}O_{29})$, when none of the water is allotted to the foreign matter present.

I find, however, that the analysis given can be interpreted as corresponding to a manganate equivalent to the acid H_4MnO_5. The following shows the analysis rearranged in conformity with this supposition :—

Coronadite :—

$Fe_4(MnO_5)_3$	1·99
$Al_4(MnO_5)_3$	1·58
K_4MnO_5	0·70
Cu_2MnO_5	0·08
Pb_2MnO_5	32·60
Zn_2MnO_5	0·16
H_4MnO_5	3·97
Mn_2MnO_5	51·24
	92·32

	92·32
Insoluble and SiO_2	7·22
MoO_3	0·34
	99·88
Oxygen surplus	0·12
	100·00

The small difference between the amount of oxygen required according to this interpretation and that which must have been determined in separating the manganese into MnO_2 and MnO_1 indicates that this interpretation may very well be the correct one. If the MoO_3 be in combination with PbO, then the subtraction of the requisite amount of PbO from the manganate would make very little difference in the result.[1] In the foregoing the whole of the last item in the analysis has, for the sake of calculation, been assumed to be potash. Assuming this interpretation to be correct the following is the approximate formula for the mineral, giving the various constituents their proper values :—

$$Mn_{21}\ Pb_6\ R''_5\ (MnO_5)_{16},$$

where R″ includes all the constituents except Pb and Mn. This is equivalent of course to $16 \times H_4MnO_5$. The formula $R''_4\ H_8\ (Mn_{12}\ O_{29})$ given by Hillebrand is equivalent to $H_{10}\ Mn_{12}\ O_{29}$ and this to $H_{22}\ Mn_6\ O_{29}$, which equals $6\ (H_4MnO_5)—H_2O$.

It thus seems as if coronadite may fairly be regarded as closely allied to hollandite and psilomelane, and as forming with these two minerals a well-marked group of minerals, namely manganates corresponding to the acid of the formula H_4MnO_5. The fact that coronadite is fibrous is a point of interest because there is also a fibrous variety of hollandite at Kájlidongri.

We can summarize the chief features of these three minerals by saying that psilomelane is an apparently amorphous manganate of manganese, barium, iron, potassium, hydrogen, and other bases; that hollandite is the crystalline form of psilomelane ; and that coronadite is a form characterized by the presence of a large quantity of lead, which may be regarded as the equivalent of the barium so often found in psilomelane and hollandite.

Up till now psilomelane has usually been treated in text-books on mineralogy as a sort of derelict amongst the oxides, although Dana

[1] The oxygen surplus becomes 0·14 instead of 0·12.

recognizes it as a manganate. Now that companions have been found for it, it can be made with them into a new group of minerals, the manganates.

For the sake of comparison with the analysis of coronadite as rearranged by me in terms of manganates above, I give below four analyses arranged in the same way, two of Indian hollandites, and two of Indian psilomelanes. No. 1 is the original analysis of crystalline hollandite from Kájlidongri by Mr. H. J. Winch; No 1146 represents massive fine-grained hollandite from Bálághát in the Central Provinces; No. 1157 a portion of a hard grey hepatiform concretion of psilomelane from Guguldoho in the Nágpur district, Central Provinces; and No. A. 380, a bluish grey minutely pisolitic psilomelane from Tekrasai, Singhbhum district, Bengal. The three last analyses were made by Messrs. J. and H. S. Pattinson of Newcastle-on-Tyne. The analyses incidentally illustrate what a variety of bases may take the place of the H. in the formula H_4MnO_5.

	Hollandite.		Psilomelane.	
	No. 1.	No. 1146.	No. 1157.	No. A. 380.
$Fe_4(MnO_5)_3$	20·76	8·71	2·95	0·41
$Al_4(MnO_5)_3$	2·36	2·61	0·38	0·75
Ba_2MnO_5	23·50	3·95	0·04	20·14
Ca_2MnO_5	...	0·59	0·40	0·15
Mg_2MnO_5	...	0·82	0·41	0·57
K_4MnO_5	...	5·12	4·79	0·31
Na_4MnO_5	...	1·04	0·82	0·27
$CoMnO_5$	...	0·08	0·17	0·42
Ni_2MnO_5	...	...	...	0·34
Cu_2MnO_5	...	...	...	0·13
Zn_2MnO_5	...	...	...	0·49
H_4MnO_5	...	3·96	13·12	12·73
Mn_2MnO_5	53·59	70·71	74·74	62·28

	Hollandite.		Psilomelane	
	No. 1.	No. 1146.	No. 1157.	No. A. 380.
	100·21	97·59	97·82	98·99
SiO_2	...	1·40	0·25	0·05
Sulphur	...	0·021	0·021	0·039
P_2O_5	...	0·046	0·838	0·737
As_2O_5	..	...	0·003	...
CuO	. .	...	0·002	0·00
TiO_2	...	0·03	0·01	...
Moisture at 100° C.	...	0·15	0·25	0·45
	100·21	99·237	99·194	100·266
Oxygen assumed	0·37	...	...	0·18
Surplus oxygen	...	0·61	0·80	...
	99·84	99·847	99·994	100·086
Specific gravity	4·95	4·59	4·26	4·54

In explanation of the few constituents given in the first analysis it may be said that the analysis was made on the mine, when elaborate apparatus was not available. Constituents other than those mentioned must occur in small quantity.[1] The items forming the last two lines of the foregoing analyses indicate whether there was less oxygen in the analysis than was required for the foregoing interpretation, or whether there was more. In the two cases of a surplus of oxygen it is seen that the amount of the surplus is somewhat large. If this be considered too large to be due to experimental error, then it is explicable on the hypothesis that a small portion of the manganese is present in the form of manganic manganate, $Mn_4(MnO_5)_3$.

[1] See footnote on page 77 of paper 'Manganese in India', already quoted.

A much fuller treatment of the subject of the composition of hollandite and psilomelane will be found in the accounts of these minerals in a monograph on the manganese-ore deposits of India now in the press, and to be published in the *Memoirs, Geol. Surv., Ind.*

NOTE ON AN OCCURRENCE OF WOLFRAM IN THE NÁGPUR DISTRICT, CENTRAL PROVINCES. BY L. LEIGH FERMOR, A.R.S.M., B.SC., F.G.S., *Assistant Superintendent, Geological Survey of India.*

History.

THE discovery of the existence of wolfram in the Nágpur district of the Central Provinces is another example of those happy chances that have so often led to the location of valuable mineral deposits. It seems that Mr. J. Kellerschon of Nágpur, agent in India for the Carnegie Steel Company, was conducting prospecting operations for manganese in this district, to the south of the Bengal-Nagpur Railway line, where ores of this mineral had not up till then been found—and still have not, as far as I know. An explorer had found some pieces of rock showing black stains and was instructed to put down a prospecting pit at the place where the stained rock was supposed to have come from. The result was the extraction of pieces of quartz and mica-schist, instead of manganese-ore. Mr. Kellerschon was shown pieces of the material extracted and saw that the pit had been put down in a place where there was little probability of finding manganese-ore. Mica-schist is, however, one of the frequent associates of manganese-ore deposits in the Central Provinces, and consequently Mr. Kellerschon instructed his prospector to go on with his pit and take a sporting chance of finding manganese. The result was that at a depth of only 6 feet below the surface a black mineral was found in the quartz. This was sent to the Geological Survey Office for identification and recognized as wolfram, the actual test for this element being made by Mr. G. G. Narke, a student from Nágpur working in the Geological Survey laboratory. This find aroused considerable interest, and consequently I took the opportunity, whilst examining some manganese deposits in the Central Provinces in December last, to pay a short visit to the wolfram locality. Here I must take the opportunity of thanking Mr. Kellerschon for sending further specimens of the mineral to the Geological Survey and showing me all the occurrences that he had found as the result of further prospecting operations.

The wolfram deposit lies within the boundaries of Agargáon village area or mauza, in the Umrer tahsil. This village lies on the south bank of the Kanhán river at a point about 7 miles south-east of Maunda (9 miles by bullock-cart road). Maunda is 20 miles east of Nágpur on the main road from Nágpur to Raipur. The pit where the wolfram was first found lies about ¾ mile south by a little west of the village, on a low ridge of mica-schists striking N. 65° E.

Situation.

The following is an extract from a letter from Mr. Kellerschon to Mr. C. E. Low, Director of Industrial Surveys, Central Provinces, and is the first account giving details of the occurrence :—

'In the village of Agargáon, Umrer Tehsil, Nágpur district, S. 8° W., about 3,980 feet from the village site, the wolframite was first encountered in a test pit at a depth of 6 feet. The pit was sunk on a low ridge showing numerous outcrops of mica-schist with quartz veins and with a strike N. 65° E. and dip 85° to the north. This belt of micaceous schists exposed about 60 feet wide can be traced along the strike all through the area of Agargáon into the adjacent village of Palegáon to the south-west and also into the bed of the Kanhán river to the north-east of Agargáon, then disappearing under the drift of the high north bank of the river in the village of Borgaon.

'In the river bed a slight change of strike is observed now being about N. 80° E.'

Mr. Kellerschon further says that although the mica-schists with quartz veins disappear on the other side of the river for some distance, yet, according to Mr. S. O. Holmes, they re-appear in the village of Lohára, whence he (Mr. Holmes) has traced them through the villages of Chaukhan (Chowkund), Peotha, and Kandhi (Kondhee), a distance of about 3 miles, with a persistent strike of N. 65° E.

Mr. Kellerschon has taken up an exploring license, pending the grant of a prospecting license, over the portion of this mica-schist belt lying within Agargáon mauza limits, Mr. H. M. Hance of the Indian Manganese Company has applied for the extension of the belt to the south-west in Palegáon village, and Messrs. S. O. Holmes, E. G. Beckett, and Hance have applied for the extension of the belt to the east-north-east of Agargáon on the other side of the Kanhán river. The only portion of the belt in which wolfram has yet been located is the Agargáon portion, and consequently I devoted the limited time at my disposal to the examination of this part only. I fully agree with the account given by Mr. Kellerschon as far as it applies to this portion of the belt.

Towards the western end of the Agargáon portion there is a good cross-section of the schists exposed in a small watercourse cutting across the belt approximately at right angles. The total distance across the strike of the rocks is about 200 feet, with the dip sometimes very steep to the north, sometimes very steep to the south side of the strike, and sometimes vertical, the average dip being probably vertical. This applies also to all the sections seen in the trenches to be noticed below. The rocks seen in this section consist of micaceous schists, frequently containing abundance of tourmaline; with some layers of fine-grained tourmaline schist; some of the less crystalline form of schist known as phyllite and some of fine-grained quartzites The quartzites, which occur towards the south end of the section, are of subordinate importance as compared with the mica-schists, and there is every gradation between the quartzite, through micaceous or sericitic quartzite, to the mica-schist. Interbedded with these schists there are several lenticular masses of quartz varying up to 8 inches thick. The mica of these schists is chiefly a white mica. None of them where I broke them showed any signs of wolfram.

Geology and mode of occurrence.

From this watercourse the schists can be traced continuously to the east-north-east along a low ridge, there being frequent outcrops of vein quartz intercalated between the schists and standing up above them on account of the more resistant nature of the quartz towards weathering-agents. At 300 feet to the east we found a little wolfram *in situ* in the outcrop of quartz. From here the wolfram has been located at intervals by means of pits and trenches for a total distance of about 1,350 feet. The belt of schists with intercalated quartz veins continues with the usual east-north-east strike as far as the river some 1,900 feet distant; but no wolfram has been found in the outcrops, nor have any trenches or pits yet been made on this portion.

In the portion in which the existence of wolfram has been proved four trenches have been put across the strike of the ridge. None of these have been carried to a greater depth than 8 feet, because the Deputy Commissioner of the district has fixed this as the maximum depth to which the surface of the land may be turned up under an exploring license. When a prospecting license has been obtained and Mr. Kellerschon has been able to work down to as great a depth as he chooses, I shall hope to visit the occurrence again and make a more careful and detailed examination than was possible this time.

The rocks seen in the trenches are similar to those seen in the section referred to above. They consist chiefly of micaceous schists with interbanded tourmalinic varieties of the same, and layers of a fine-grained dark greenish black schist that is seen under the microscope to consist practically entirely of an aggregate of tiny tourmaline prisms, with a very small amount of interstitial quartz. Each trench also shows several quartz veins interbedded in the schists and varying in thickness from a small fraction of an inch to as much as 18 inches, though this thickness is exceptional. In some cases the quartz veins are in the mica-schists, but they tend to be more closely associated with the tourmaline-schists. When in the latter the quartz sometimes takes the form of a series of numerous small veins close together, and often joined up by small cross stringers.

The quartz veins show much evidence of having been crushed. In the first place the quartz is usually granular like a coarse-grained quartzite. In a hand-specimen, however, there is usually considerable variation in the size of the quartz grains from point to point, and sometimes there are residual patches, an inch or more across, of quartz that has escaped granulitization. Under the microscope the separate grains of quartz are seen to interlock with very intricate boundaries; they also show undulatory extinction, although the strength of this phenomenon varies, and in some cases is practically absent. I know that it is possible for such granulitization and strain phenomena to have been produced by strains set up during the deposition of the quartz. But I think it is more probably due to the veins having been crushed. The veins besides being granular are frequently laminar, splitting into tabular pieces parallel to the walls of the vein. When like this the lamination planes frequently contain thin layers of mica varying in colour from golden to whitish. Further evidence of crushing is seen in the brecciation of the tourmaline-schist and the wolfram noticed later.

In the second trench from the watercourse section there are 7 veins in a thickness of 6 feet. Most of them are an inch or less in thickness, but one is 4 inches and another 12 inches thick. There are also several thin stringers. The most southern vein, which is the 1-foot one, contains some brecciated patches of the dark tourmaline-schist. The breccia is cemented by mica-schist. The dark green tourmaline schist adjoining this vein is also brecciated and cemented by mica-schist, with the mica flakes parallel to the schistosity of the tourmaline-

schist. The mica being a light coloured variety the contrast is very striking. It is difficult to offer any adequate explanation of this curious phenomenon. Perhaps, when the tourmaline-schist was brecciated, some powdered mica-schist found its way between the pieces of tourmaline-schist, and was consolidated into schist again on a renewal of pressure. On the assumption, put forward below, that the tourmaline-schist is a product of the metasomatic replacement of the mica-schist, a more probable explanation would be that the veins of mica-schist in the tourmaline-schist represent portions of the schist that have escaped this replacement.

There seemed to be wolfram in most of the veins mentioned above.

The third trench from the watercourse section was 133 feet long. It showed several quartz veins of thicknesses of 3 and 4 inches, with one expanding to as much as 18 inches in one place. There were also a large number of very thin veins wherever the tourmaline-schists appeared. As in the second trench, these tourmaline-schists were brecciated by thin veinlets of mica-schists with the schistosity parallel to that of the tourmaline-schist. Many of the quartz veins and veinlets contained wolfram, the total width of the zone in which the wolfram was found being probably as much as 70 feet; but on this point I had partly to take the word of the miners as to which veins had yielded wolfram and which had not for the simple reason that the wolfram is very unevenly distributed through the quartz veins, so that sometimes the particular portion of a vein exposed seems to be crowded with the mineral and sometimes quite free from it.

I have mentioned in the last paragraph the extremely irregular distribution of the wolfram in the veins. Taking the average of all the veins exposed in the various trenches it is probable that for every cubic foot of quartz containing wolfram, several are extracted free from it.

Characters of the wolfram.

In size the wolfram individuals vary from very small up to as much as 4 to 5 inches across; between ½ and 2 inches seems to be the most usual size. The wolfram tends to be idiomorphic, but owing to its brittleness the pieces of rock usually break right across the wolfram instead of along the boundaries of the crystals. The only example I have found showing a well-marked crystal form is a small embedded tabular prism showing the forms *a*, *m*, and *b* in the prism zone, and

with the terminal faces not exposed. It is embedded in mica-quartz-schist. As seen on the fractures of the crystals embedded in quartz, the most general shape of the wolfram seems to be oblong, with the length about 3 to 4 times the breadth. As far as I can judge from these embedded individuals the simplest shape is a tabular crystal flattened parallel to the ortho-axis, *b*. The wolfram does not always show this tabular shape, however; it is sometimes more or less equi-dimensional in all directions, and often irregular in shape. There are also many examples showing that what was originally one individual or crystal of wolfram has been fractured and re-cemented by vein quartz, thus giving further evidence that the veins have been crushed. When the wolfram is broken it usually splits along the perfect cleavage parallel to the clino-pinacoid, *b*. Sometimes the brilliantly shining cleavage faces show that the mineral is twinned, probably with the composition face parallel to the ortho-pinacoid, *a*. The trace of the composition plane is therefore parallel to the long direction of the rectangular cleavage surfaces. Sometimes, however, the mineral is seen to be broken up into numerous bands at right angles to the long direction of the cleavage surface. These bands reflect light at slightly different angles, and are evidently due to the straining and bending of the mineral, and afford still further evidence that the veins have been crushed. In addition to the perfect cleavage parallel to *b* the mineral occasionally shows a rather good parting in a direction at right angles to the cleavage, and hence probably the known parting parallel to *a*. The mineral also shows the usual resinous fracture, is very weakly magnetic, and has a dark reddish black streak.

Besides occurring in the quartz the mineral sometimes occurs in the mica-schist close to the quartz; but the mica-schist is then extra rich in quartz.

Subsequent to the original find of wolfram *in situ* in the quartz veins several small pockets of weathered out nuggets have been found at the surface. These nuggets are sometimes 1 to 3 inches in diameter, and often consist practically entirely of wolfram.

Origin of the deposits.

I have not yet sufficient evidence to be able to deal satisfactorily with the origin of the wolfram. A few points, however, seem fairly certain. They are:—

1. The wolfram occurs in quartz veins, intercalated in a series of mica-schists and tourmaline-schists, and tending to be more closely associated with the tourmaline-schists.

2. The schists are a part of the Dhárwár series.
3. The quartz veins have been granulitized and in places squeezed into lenticles; the enclosed wolfram has often been brecciated; whilst portions of the tourmaline-schist have been enclosed in the quartz, and the neighbouring tourmaline-schist also brecciated.
4. The tourmaline-schist breccia has the interstices of the breccia filled with mica-schist.
5. The close association of the tourmaline and the wolfram suggests that these two minerals are genetically connected. If so, the quartz must, at least in part, have been deposited later than both.

As a provisional hypothesis as to the origin of these deposits I would suggest that the tourmaline has been introduced into the schists adjoining the veins by metasomatic replacement. The presence of tourmaline in association with mineral veins is usually taken to indicate that the formation of those veins took place under higher temperatures than in other cases, so that the conditions were often what is known as pneumatolytic, *i.e.*, the mineralizing temperature was above the critical temperature of water. Hence in this case we may put forward as a working or provisional hypothesis, to be proved or disproved when more evidence becomes available, that mineralization took place along fissures parallel to the bedding or stratification of the rocks by the agency of heated vapours, with the metasomatic introduction of tourmaline into the wall rocks. The tourmaline-schist might on this view be due to the metasomatic replacement of the mica-schist, although of this I have no evidence. We can suppose that at about the same time the wolfram was deposited, and then both the tourmaline-schist and the wolfram brecciated in parts by movements in the fissure and neighbouring rocks. The quartz was probably partly deposited concurrently with the wolfram and partly after the brecciation; the last deposited quartz must have filled in the spaces between the breccia. Further movements must have crushed the last deposited portion of the quartz, or else it must have been granulitized at the time of deposition.

Two sorts of quartz veins.

When walking along the outcrops of the mica-schist I noticed that in addition to the crushed quartz veins there were also some of the uncrushed opaque white quartz so common in the Archæan rocks. As these did not contain wolfram, as far as I could ascertain, I imagined that here I

had found a point to which the attention of prospectors might be directed as a help, should they try to find wolfram in quartz veins elsewhere. In the trenches, also, although most of the veins were of the crushed variety, there were occasional ones of the uncrushed variety. These, also, as far as I could see, did not contain wolfram, and the miners also told me they had not yielded any wolfram. When, however, I carefully examined the considerable number of specimens I had selected from the ore in the foreman's bungalow I found two small pieces of the uncrushed white quartz containing wolfram. I had also noticed in the veins in the trenches that in places the crushed veins showed small patches of uncrushed quartz. From this it seems probable that a portion of the wolfram-bearing quartz escaped crushing. But I do not know if the veins that seem to be uncrushed throughout their whole outcrop belong to a later generation or are merely part of the wolfram-bearing series that have escaped crushing. It is possible that there are really two series of veins here, and that the two specimens referred to above were obtained from the uncrushed portion of the older series of crushed veins, and that the uncrushed veins belong to another generation and are really free from wolfram. In any case it would seem advisable for prospectors searching for wolfram in other parts of this district or of the Central Provinces to direct their attention first to interbedded crushed quartz veins, and then to search the interbedded uncrushed veins, leaving the uncrushed veins that cut across the strike of the schists to the last as being almost certainly of a later age than the veins here noticed as containing wolfram, and hence not likely to contain this mineral.

Economic value of the deposits.

With regard to the possibility of making a financial success of the Agargáon occurrence, it is obvious that owing to the irregular and pockety distribution of the wolfram in the quartz it is difficult to speak with certainty. According to Mr. Kellerschon in a letter written to me in January 1908:—

'We have now 20 bags weighing 50 lbs. each of rich nuggets, about 1 ton of well mineralized quartz and 1½ tons of mineralized.'

This amount of wolfram has been obtained as the result of a comparatively small amount of development work, and if only the veins continue to yield in depth the same proportion of mineral as they have yielded in the first 8 feet I should think there could be little doubt as to the paying nature of the occurrence. Should these veins

be found to continue in depth as rich as they have proved at the surface I believe it is Mr. Kellerschon's intention to erect concentrating plant on the spot. Should the other concessionaires on the strike of the wolfram-bearing belt of schists find wolfram in their claims, they will probably arrange for the Carnegie Company's mill to treat their ores as custom-ore.

Composition of the ore.

An analysis of some broken crystals and fragments of wolfram sent by Mr. Kellerschon to the Carnegie Steel Company in America gave the following result:—

Tungsten	51·59
Iron	14·50
Manganese	2·94
Silica	3·40
Phosphorus	0·018

This is equivalent to—

Tungstic oxide (WO_3)	65·05
Ferrous oxide (FeO)	18·64
Manganese oxide (MnO)	3·73
Silica (SiO_2)	3·40
Phosphoric oxide (P_2O_5)	0·04
	90·86

It will be seen that there is a deficit of about 9%; I do not know what this represents, for I did not see the specimens that were analysed. It might be some attached mica or tourmaline-schist. The 3·73% MnO is equivalent to 3·78% FeO, making a total of 22·42% FeO. 65·05% WO_3 requires only 20·19% FeO for $FeWO_4$, so that there is an excess of over 2% of FeO belonging perhaps to the other mineral. According to Dana the ratio of iron to manganese in wolfram is chiefly 4 : 1 and 2 : 3, but varies from 9 : 1 to 2 : 3. This one has Fe : Mn. = 4·9 : 1.

Valuation and price of wolfram.

Owing to the limited demand for wolfram the market price is subject to sudden fluctuations according to the variations in the available supplies, but there seems to be a tendency for the price to become steady as the uses and the number of mines opened up increase. The

following is given by Mr. W. E. Greenawalt[1] as a schedule on which one mill for concentrating ore in Colorado makes purchases of ore :—

Basis for purchasing tungsten ore.

Percentage of WO_3.	Value per ton.	Percentage of WO_3.	Value per ton.
	$		$
3	10	20	100
4	15	30	180
5	21	40	280
10	46	50	400
15	71	60	570

Concentrates are purchased in the same region on the basis of $9·50 per unit for concentrates containing 60 per cent. or more, and $8·50 for concentrates containing between 50 and 60 per cent. tungstic acid ; so that concentrates containing 50, 60, and 70 per cent. of WO_3 are worth $425, $570, and $665 per ton, respectively. For comparison with the above we may take the quotations in the *Mining Journal.* In the number for October 19th, 1907, the price is given as 40 shillings a unit (presumably of oxide), in that for December 7th as 30 shillings, equivalent roughly to $10, and in that for March 21st, 1908, as 26 to 27 shillings, $7·50, and a little over $6, respectively. This decrease in price is probably connected with the financial troubles in America, and, if so, may be temporary only.

Literature.

For an interesting account of the method of working the wolfram deposits of Colorado reference may be made to an article on pages 951 to 952 of the *Engineering and Mining Journal* for May 18th, 1907. Another recent article on wolfram to which reference may be made is one by Mr. W. Lindgren[2] on 'Some Gold and Tungsten Deposits of Boulder County Colorado.'

[1] *Eng. Min. Jour.*, p. 952, May 18th, 1907.
[2] *Economic Geology*, II, pp. 453-463 (1907).

A paper read by Messrs. A. Treloar & G. Johnson before the Institution of Mining and Metallurgy[1] deals with the separation of cassiterite from wolfram; whilst an article by Mr. F. L. Hess[2] in the *Mining Journal* treats of the price and uses of tungsten.

Occurrence of wolfram in the Indian Empire.

The occurrence of wolfram noted in this paper is of especial interest on account of the fact that it has only once been previously recorded from the Peninsula of India, namely, from the Házáribágh district, Bengal[3]. But it has also been found at several localities in Burma, from the Shan States to Tenasserim.

[1] *Mining Journal*, p. 642, Nov. 23rd, 1907.

[2] *Ibid*, p. 635. Advance chapter of 'Mineral Resources of the United States, 1906.

[3] *Rec., Geol. Surv. Ind.*, XXI, p. 21 (at end), (1888).

MISCELLANEOUS NOTES.

Note on an Occurrence of Alum at Mormugao. (With Plate 43).

Alongside the West of India Portuguese Railway at Mormugao, about 100 yards from the Burma Oil Company's tanks in the direction of the railway station, there is an interesting cliff section of rocks that are probably, but not certainly, of Dhárwár age.

The rocks in this section are considerably altered; but, as far as I could tell, they consist of bedded argillaceous rocks with some associated basic igneous rocks. There are two separate bands of the basic rocks. One consists of a fined-grained chloritized igneous rock with uralite and pyrite, and is best termed an epidiorite; the other is a medium-grained altered diabase, also containing pyrite. The argillaceous rocks are mostly very soft, being now largely in the condition of lithomarges stained with different coloured oxides of iron, so as to look like ochres. The igneous rocks also seem to pass into lithomarge. Traversing all these rocks are numerous veins of limonite forming in some places a network. These veins may be as much as 1½ inches wide, but are usually considerably less. The limonite varies in character. In some places, especially in the igneous rocks, it is parallel-fibrous, the fibres being disposed at right angles to the walls of the veinlet. In other places it assumes a dull yellow-brown compact form. The outer surface of these rocks is often coated with a deposit of mammillated limonite, of which the mammillæ average 1 to 2 inches across, and show when broken open concentric layers of slightly different character. On climbing up the section one finds that the number of veinlets of limonite increases in quantity the higher one goes, until at a height of perhaps 50 feet above the bottom of the section the rocks pass into a capping of laterite.

At one point at the bottom of the section the argillaceous rocks are less decomposed than elsewhere. They are definitely bedded and show a well-marked dip at an angle of about 40° to the N. 20° W. When broken open the rock is found to be soft and tinted in various shades of grey, except where it is iron-stained, in which case it shows various shades of greenish yellow and yellow to brown. Even here the rock is too altered for it to be possible to say what it was in its fresh form. One can suggest either a slate, a phyllite, or an argillaceous quartzite. Under the microscope it is partly clouded and partly fine-grained quartz, with numerous tiny specks of what is probably pyrite.

The surface of the rock here exposed is at right angles to the bedding, the thickness shown being about 5 feet. The interest of the section lay in the fact that this surface, for a length of 24 feet along the dip, was encrusted with patches and lines of snow-white alum, oriented roughly parallel to the dip of the rocks. The efflorescences took the form of crenulated ovals and drawn-out ellipses, with a central area of rock free from the incrustation (see Pl. 43). In places the surface of these incrustations took the form of small mammillæ. The thickness of the incrustations was on the average about $\frac{1}{4}$ inch or a little more. Occasionally the alum was yellow, due to iron staining. As the band of rock was followed up the section the incrustation was seen to cease, except for very small lines of it. The rocks at the same time seemed to be drier, and to be more often iron-impregnated.

The source of the alum was indicated by the detection in one specimen, taken from the lower part of the section, of a patch of crystalline pyrite passing into limonite, and by the pyrite noticed under the microscope. Under the influence of percolating waters the pyrite must have been decomposed, and sulphuric acid formed by oxidation. This acid then combined with some of the alumina and potash of the argillaceous rock with the formation of the aluminium and potassium sulphates. The water, on oozing out at the surface of the rock, evaporated and deposited its burden as alum. According to Mr. Becher, the British Consul at Goa, by whom my attention was drawn to this occurrence, the mineral is now in process of formation, and when the rock is scraped free of the alum a further deposit of it forms after a while. Even supposing there was originally a considerable amount of the argillaceous rock containing pyrite, it is not probable, owing to the way in which all the rocks in this neighbourhood have been altered, that there is now obtainable any large quantity of such rock still containing its pyrite. But should any spot be found where a large quantity of such rock could be easily quarried, it might be worth considering whether it would be profitable to make use of it for the manufacture of alum.

A specimen of this efflorescence was sent by Mr. A. Ghose, who was with me at the time of my visit to this occurrence, to Mr. D. Hooper of the Indian Museum, where it was analysed with the result shown in column I below, the theoretical composition of potash alum being given in column II.

	I.	II.
Potash (K_2O)	7·69	9·9
Alumina (Al_2O_3)	9·74	10·8
Sulphur trioxide (SO_3)	36·04	33·7
Water (H_2O)	46·23	45·6
Insoluble matter	0·30	...
	100·00	100·00

Although the agreement of this analysis with the theoretical composition is not very exact, yet it is sufficiently close to show that the mineral is *kalinite* or potash alum

$$K_2SO_4\ Al_2(SO_4)_3 + 24\ H_2O.$$

[L. L. FERMOR.]

Occurrence of the genus *Orbitolina* in India and Persia.

My colleague Mr. Hayden has brought to my notice, amongst the collections of the Geological Museum, several rock-specimens containing *Orbitolina*, a genus whose existence had not yet been recorded in India. Some of these specimens were collected by Mr. Hayden in a greatly crushed limestone on the east side of the Burzil (Dorikoon) pass, between Gurez and Astor, in north-west Kashmir. Other specimens collected by Mr. Griesbach are labelled "Upper Firaimán beds" and were collected five miles north-west of Firaimán in Persian Khorasán. They are accompanied by incomplete specimens of a *Pyrina* resembling the Cenomanian species *P. Desmoulinsii* d'Arch. The Firaimán specimens of *Orbitolina* are beautifully preserved. They have the shape of a very depressed cone, the base of which, shaped like a still shallower inverted cone, is ornamented with radiating ribs; some of the specimens are almost discoidal. The usual diameter is about 5 mm., the greatest thickness, 1·2 to 1·7 mm. The Kashmir specimens are slightly larger, reaching 8 mm. in diameter, and 2 mm. in thickness, but are similar in shape.

The palæontological material is insufficient for fixing exactly the age of the beds. According to Douvillé (B. S. G. F., (3), XXVIII, 1900, p. 225), the various species of *Orbitolina*, which are difficult to distinguish from one another, range from Upper Barremian to Cenomanian.

[E. W. VREDENBURG.]

Preliminary note on the geological age of the coal at Palana in Bikanir, Rajputana.

The eocene age of this coal-field was established, at the time of its discovery, by Mr. La Touche (*Records, G. S. I.*, Vol. XXX, pages 122-125, 1897). Some fossils from the beds associated with the coal, recently forwarded to

the Geological Survey by Mr. J. W. Jervis, enable us to establish its exact horizon with greater precision. Amongst this collection, the following species can be identified : *Ostrea multicostata* Desh., *Nummulites atacicus* Leym., *Assilina granulosa*, d'Arch., the two latter of which conclusively establish that the rocks containing them are identical in age with the subdivision of the eocene known in India as the "Laki group," which is the coal-bearing formation in Balúchistán and in the Punjab. The Laki group includes the older portion of the middle eocene of India. In Western Sind, the Lower Ranikot of lower eocene age also contains coal, but this is a formation of very local occurrence. The Khirthar group which overlies the Laki, and which, like it, has a considerable geographical extension, appears to be barren of coal. The abovementioned observations concerning the age of the Palana coal constitute one more instance to be added to the already numerous ones in which coal-seams have been found associated with beds belonging to the Laki group, both in the western and eastern districts of India.

[E. W. VREDENBURG.]

Preliminary note on the Indian occurrence of *Ostrea multicostata*, Deshayes, and other ribbed species of *Ostrea*.

In the preceding note on the age of the Palana coal, I have mentioned *Ostrea multicostata* as one of the fossils occurring in the coal-measures of that locality. Its identification is based upon a single incomplete specimen whose reference to the species in question has been established by comparison with better preserved material from other localities. *O. multicostata* has been mentioned more frequently than any other species of *Ostrea* in works dealing with the geology of the Tertiary in India; but although the species really does occur abundantly in this country in strata of middle eocene age, the previous references are mostly erroneous. In order to dispose definitely of the doubts connected with this subject, I have, by direct comparison with the specimens preserved in the Geological Museum in Calcutta, carefully verified the exact species referred to, in every instance where the publications of the Geological Survey mention the supposed occurrence of *O. multicostata.* I intend giving an account of this investigation with illustrations constituting a secure basis for future investigations. As the preparation of the figures will cause a delay of several months, I take the present opportunity of giving a concise summary of the results arrived at.

The first illustrated reference to *O. multicostata* is in d'Archiac and Haime's Description of the Nummulitic Fauna of India (1853). The fossil which they figured, and which they regarded as a variety of Deshayes' species is not the eocene shell, but a newer form first described as *O. angulata* by J. de C. Sowerby (Trans. G. S., (2) V, Pl. XXV, fig. 17, 1840) from a specimen collected by Grant in the Gáj beds of Kachh. In their synonymy, the authors of the "Description" have referred their specimens, which were obtained from the Gáj of Sind, not to *O. angulata*, but to another Kachh species erroneously referred by Sowerby to *O. flabellula*, Lamk. (Pl. XXV, fig. 18, of Sowerby's description). The two species are very closely related to one another, and as they both occur in Sind, they are perhaps both represented in the collection described by d'Archiac and Haime, who have referred their description to one of them and figured the other. Wood (1861, *Monograph of the Eocene bivalves of England*, p. 21) was aware of the distinctness of Sowerby's two species, for he rightly remarks that *O. angulata* more nearly resembles the true *O. flabellula* than the fossil referred to the European species by Sowerby. Wynne, in his description of the geology of Kachh (1872, *Mem. G. S. I.*, IX), has kept both forms distinct and, from the references in his Memoir, as well as from his collections preserved in the Calcutta Museum, it is evident that they never occur together. Wynne has applied the name *O. angulata* to the form figured as such by Sowerby, and figured by d'Archiac and Haime as *O. multicostata*, while he has transferred the name *O. multicostata* to the other form, that figured by Sowerby as *O. flabellula*.[1] Blanford, in the Manual of the Geology of India (1879), and in the Geology of Western Sind (1879, *Mem. G. S. I.*, XVII), has united both species under the name *O. multicostata* and has been followed by Fedden (Mem. XVII, p. 204). *O. angulata* is figured as *O. multicostata* in the "Manual" in Plate XVI, illustrating the leading fossils of the Gáj formation; unfortunately this figure is merely a copy of the uncharacteristic one given by d'Archiac and Haime, which represents a specimen in which the exceptional state of preservation of the upper valve conceals the broad flange-like expansion which constitutes the most distinctive feature of the lower valve. Consequently the two valves appear

[1] I am aware that the transfer of the name *O. plicata* to Lamarck's *O. flabellula* has been sanctioned by such distinguished authorities as Cossmann Oppenheim, Sacco, and Rovereto, but the present discussion is sufficiently involved without this crowning confusion. There is but one definition of *O. flabellula*, while there are three of *O. plicata*, one of Solander, one of Chemnitz and one of Deshayes. The use of the name *O. flabellula* cannot lead to any confusion, and it is preferable to discard entirely the name *O. plicata* in spite of the laws of priority.

to differ only slightly in size, and, as the internal characters of the shell are not figured, the illustration can easily pass for a representation of *O. multicostata*, and indeed, comes so close in appearance to some of the eocene specimens of the true *O. multicostata* from the Laki range in Sind, that I myself was led to the conclusion that the eocene shell must have been represented in the collection examined by d'Archiac and Haime (*Rec., G. S. I.*, XXXIV, p. 269). A closer study of the illustrations and text shows however that it is undoubtedly the Gáj species *O. angulata* that these authors have figured.

The characteristic features of *O. angulata* are the oval-deflected "flabelliform" shape of the lower valve, ornamented with regular, equally distributed angular ribs, crossed at varying intervals by foliaceous lamellæ of growth, the extremely small hinge, the crescentic, oblique, posteriorly attenuated muscular impression, resembling in shape and position that of *O. flabellula* and *O. ventilabrum*, the curious spoon-shaped body-chamber surrounded by a broad, flat, flange-like rim, extending, in well-preserved specimens, a great deal beyond the relatively very small operculum-like upper valve. The species has been correctly diagnosed by Noetling (1901, Miocene of Burma, p. 110), who, apparently unaware of Sowerby's name *O. angulata*, has distinguished it as *O. Blanfordiana*. The latter name can be adopted instead of Sowerby's, should it be considered unadvisable to use the same specific name in two genera so closely related to one another as *Ostrea* and *Gryphæa*, as there is a previously defined *Gryphæa angulata*, Lamarck, a recent species of the Indian Ocean. The external appearance of the lower valve is practically identical with that of *O. ventilabrum*. as has already been noticed by Dr. P. Bruhl, of the Sibpur Engineering College, in some manuscript notes communicated to the Geological Survey. Their resemblance is especially striking in the case of the variety of *O. ventilabrum* with angular ribs, Wood's *O. prona*. This external appearance is very well shown in Sowerby's careful drawing, but as the figure is apparently not drawn to full scale, and as the internal characters of the shell are not shown, it might very well pass for the much smaller *O. flabellula*, as has been noticed by Wood.

There is no possible hesitation, however, with respect to Sowerby's excellent illustration of the second species, for the external characters, at least, of both valves are so clearly represented as to make one wonder how it could have been referred to *O. flabellula* by Sowerby and to *O. multicostata* by d'Archiac and Haime and their successors.

The more numerous, less angular ribs, some of which are thicker than the others and diversified here and there by spines, the absence of prominent lamellæ of growth, the more orbicular shape, and the still more extraordinary development of the flange-like expansion of the lower valve and still more diminutive size of the upper one, are the characters that distinguish this shell from Sowerby's *O. angulata*. I propose to call it *O. latimarginata*.

O. angulata occurs both in the Upper Nari and Gaj, *O. latimarginata* only in the Gáj, and, whenever precise information is available, it appears to characterise the uppermost zone of that formation. As the two species never occur together, the second probably replaces the first in the highest beds.

D'Archiac and Haime's unsatisfactory illustration of *O. angulata*, Sow., which they labelled *O. multicostata*, and erroneously attributed to the eocene, has misled Mayer-Eymar and von Pavay (1871, Geology of the Klausenburg region), and Frauscher (1886, Lower Eocene of the Northern Alps), into establishing it as the type of *O. orientalis*, Mayer-Eymar, a species which is evidently related to *O. multicostata*. It has a relatively large hinge, the ligament area of the upper valve, in particular, being more elongated than in *O. multicostata*, and therefore quite different from the extremely small hinge of *O. angulata*, but as d'Archiac and Haime have not figured the internal features of their specimens, and as their description of the hinge is not very clear, the authors who have dealt with *O. orientalis* were unaware of this difference. Instead of the extreme divergence of size between the upper and lower valves of *O. angulata*, the two valves of *O. orientalis* bear to one another about the same relative dimensions as those of *O. multicostata*, another character in which the geologists who have described the Klausenburg fauna have been misled by d'Archiac and Haime's illustration.

O. orientalis is not known in India. But the true *O. multicostata* is well represented in Baluchistan, in Sind, in Kachh, and in Rajputana, as one of the Laki and Khirthar species; it is found therefore in the Lutetian, throughout the same horizons which it characterises in Egypt and southern Europe.

In Griesbach's notes on Afghanistan, *O. multicostata* is mentioned as having been found in five localities, in all of which it is mentioned as a proof of the occurrence of miocene beds. (1886-1887, *Rec. G.S.I.*, XIX, XX.) These are the neighbourhood of Khaf in Persian Khorasan, the Nimaksar and Khwaja Kalandar in Badghis, the neighbourhood of Tashkhurghan in the province of Balkh, and Kilif on the Oxus. The first and last of these alleged occurrences are not represented in the collections of the Calcutta Museum. The fossil from the Nimaksar is *Gryphæa Esterhazyi* von Pavay,[1] the one from Khwaja Kalandar, *Ostrea, turkestanensis* Romanowski, and the one from the neighbourhood of Tashkhurghan an *Erogyra* probably of Cretaceous age. It must be remembered that the names

[1] These specimens are identical in every respect with Stoliczka's specimens from Sanju in Kashgaria, preserved in the Calcutta Museum, and labelled "*Gryphæa Esterhazyi*, var." by Professor Suess. The fossils both from Sanju and from the Nimaksar invariably exhibit the tongue-shaped contraction of the upper portion of the body-chamber, regarded by J. Böhm as the most distinctive characteristic of *Gr. Esterhazyi* (1903, *in* Futterer's *Durch Asien*).

published by Griesbach only represent rough determinations made in the field, away from any books of reference. Griesbach's collections contain no other fossils bearing on the question of the geological age of the strata containing the highly interesting forms *Gryphæa Esterhazyi* and *Ostrea turkestanensis*, but in Dr. Noetling's collections from the Nari beds with *Nummulites intermedius* and *Lepidocyclina dilatata* of the Lower Zhob valley in Balúchistán, there is a fossil, already alluded to by its discoverer (General Report for 1898-1899, p. 62), which appears to me undistinguishable from *O. turkestanensis*. The latter identification opens out some interesting questions which cannot be satisfactorily solved in the present state of our science. According to Koch (1897, Occurrence and extension of *Gryphæa Esterhazyi*, Journal of the Hungarian Geological Society), it seems evident that, in Transylvania, the oyster bank containing *Gryphæa Esterhazyi* is connected with strata containing *Nummulities perforatus* and *N. striatus*, which suggests a geological age at the limit of Lutetian and Bartonian. In Persian Khorasán, Bogdanowitch found *Gr. Esterhazyi* (*Gr. Kaufmanni*, var. *persica*, Bogdanowitch) accompanied by small nummulites, the specific attribution of which is uncertain, but which have also been regarded as middle eocene. Judging from the Zhob valley occürrence, *Ostrea turkestanensis* should characterise a somewhat newer horizon. In conflict with this simple conclusion, we have the evidence of Futterer's detailed section at Irkestán in Ferghana, (1903, *Durch Asien*, Vol. III), where the two species apparently occur together in the same bed, while in Bokhara, the late Dr. von Krafft found *Ostrea baissunensis*, G. Boehm, regarded by J. Böhm as identical with *O. turkestanensis*, in beds which seemed to underlie an upper Senonian formation (1899, Fossils from Bokhara, Journal of the German Geological Society). An undetected fault might account for the anomalous occurrence in Bokhara, but it will not dispose of the facts observed in the Irkestán section where both forms are found together. Two explanations suggest themselves, either that in some of the sections certain fossils are derived from an older zone, or else that the horizon of *Gryphæa Esterhazyi* is not the same in Transylvania and in Central Asia. The question must remain in abeyance until better evidence is available.

It has been noticed that in Sind and in Kachh, *O. latimarginata* (Sowerby's *O. flabellula* and Wynne's *O. multicostata*) is restricted to the Gáj, while *O. angulata* occurs in the Gáj and Upper Nari. In the *intermedius*-beds (Lower Nari), there occur two close-ribbed species belonging to the genus *Ostrea sensu stricto*, which I have interpreted as *O. cubitus*, Deshayes, and *O. Fraasi* Mayer-Eymar (see Oppenheim's lower tertiary fauna of Egypt, *Palæontographica*, XXX, 1903). The latter is the species alluded to, as undescribed, in a previous number of these Records (1904, XXXI, p. 167),

by Mr. Pilgrim, who compared it with a fossil discovered by Mr. P. N. Bose in the tertiary beds of Mayurbhanj in Orissa.[1] Mr. Bose's fossil differs from *O. Fraasi* by its larger size, and the relatively much wider spacing of the pallial punctuations of the lower valve, and crenulations of the upper one; in all other characters it is similar. It resembles a form occurring in the uppermost Gáj of Sind, probably just at the limit with the succeeding Hingláj formation.

The peculiar *O. angulata* and *O. latimarginata* of the Gáj beds do not ascend into the overlying Hingláj series, in which the strata characterised by *O. Virleti*,[2] Desh, contain close-ribbed forms referable to *O. digitalina*, Eichwald var. *Rholfsi*, Fuchs. The association of these two species confirms my previous attribution of these beds to the Burdigalian, while the underlying Gáj, with its large lepidocyclines and its fauna closely related to that of the oligocene Nari, cannot be regarded as newer than Aquitanian. As explained in a previous volume of these Records, there is every reason to ascribe a Burdigalian age to the Yenangyoung series of Burma (*Rec*., XXXIV, pp. 92, 267; also H. Douvillé: Tertiary Foraminifera of Borneo, *Bull. S. G. F.*, 1905), and it is worth noticing that one of its leading fossils, *O. peguensis*, Noetling, is probably identical with *O. Virleti*. I have not yet studied the accompanying close-ribbed *O. promensis*, Noetl. Thus the Burdigalian formation, whose occurrence in continental Asia could hitherto be asserted only in the

[1] The fossil in question was collected by me in 1901 in the Upper Zhob District. Mr. Pilgrim speaks of it as occurring in the "Upper Nari of Balúchistán", being probably misled by the labels which I wrote when I first discovered this fauna. Its exact horizon could not be determined at first sight owing to the absence of foraminifera. I was at first led to attribute to it an Upper Nari age owing to the presence of fossils closely related to those of the Gáj, for instance, *Breynia multituberculata*, described in a previous number of the present publication. It was subsequently ascertained that this echinoid exists also in the *intermedius* beds (Lower Nari) of Sind, and therefore, in my description, I left the exact age of the beds undecided (*Rec*., XXXIV, p. 271). The fossil here identified as *Ostrea Fraasi* also occurs in the *intermedius* beds of Sind which contain many other forms specifically identical with fossils from the *Breynia multituberculata* beds of Balúchistán. The Balúchistán beds appear to belong therefore to the *lower* Nari, and the relation of their fauna to that of the Gáj depends upon the general fact which constantly impresses itself upon us, that the Nari and Gáj are closely related to one another, both stratigraphically and faunistically. The connection is so close that the Gáj cannot be regarded as newer than Upper Aquitanian. I have hitherto spoken of the Gáj as Oligocene, as I included the Aquitanian in the Oligocene, in conformity with the 4th edition of de Lapparent's Treatise of Geology. In the 5th edition (1906), the Aquitanian has once more been restored to the Lower Miocene.

[2] I notice that in *Rec.* XXXIV, p. 92, I have mis-spelt this name "*Verleti.*"

region of Lake Urmia and the neighbourhood of Teherán (de Lapparent, 5th ed., p. 1605), can now be shown to ocupy enormous areas in the Mekran and in Burma, where it is represented respectively by the Hingláj and Yenangyoung series.

[E. W. VREDENBURG.]

Considerations regarding the age of the Cuddalore series.

All along the coasts of the Indian Peninsula, there is an almost continuous belt of sedimentary formations, ranging in age through Mesozoic, Tertiary, and Quarternary. Of this varied sequence, the upper cretaceous beds of the Coromandel coast are the only ones that have been carefully studied. Various older horizons of the Mesozoic have been assigned to a number of beds along the east coast corresponding with certain zones of the Upper Gondwana. An almost continuous belt of laterite encircles the entire peninsula, and it is, in part, at least, of lower pleistocene age, as is conclusively established by the presence of palæoliths of the most characteristic type, which it contains in the Coromandel regions.[1] At various localities there occur raised beaches whose stratigraphical relation to the pleistocene laterite has not been unravelled. Nothing is known scarcely regarding the frequently important formations that underlie the pleistocene laterite, but are newer than the upper cretaceous beds, and correspond therefore with some part of the tertiary. Along the Coromandel coast, where they are developed on a very important scale, these formations constitute the Cuddalore series. Further north, near the delta of the Godāvari, the Cuddalore series appears to be represented by the Rajamahendri beds (not to be confounded with the cretaceous fluvio-marine intertrappeans of that region, which underlie the Rajamahendri beds, just as the Ariyalur and Niniyur of the Coromandel coast underlie the Cuddalore sandstone). The Rajamahendri beds appear to be connected in a northern direction with sedimentary formations underlying the laterite in Orissa and Midnapur, while in the extreme south of the peninsula, the Cuddalore sandstones are more or less directly connected with strata occupying a similar position beneath the laterite of Travancore. Much further north along the west coast, sedimentary beds are known to underlie the laterite at Ratnagiri.

Fossils resembling those from the Gáj series were discovered in the infralateritic beds of Quilon in Travancore by General Cullen, and described by Dr. Carter in 1857. The only fossils obtained from the Cuddalore series

[1] The latest work on the subject of Indian stone-implements is A. C. Logan's "Old chipped stones of India, founded on the collections of the Calcutta Museum." Thacker, Spink and Co., Calcutta, 1906.

by the Geological Survey, are silicified trunks of fossil wood. During the survey of Travancore, in 1881, the locality of General Cullen's richly fossiliferous tertiary beds was never rediscovered. They were once more traced by Mr. Logan, the Resident in Travancore in 1883, but the collections that were forwarded by him to Calcutta cannot now be found. All the palæontological evidence at present available from this immense tertiary formation, which extends over a length of some two thousand miles, consists in the fossils mentioned in the previous note, which were discovered by P. N. Bose in Mayurbhanj, and the extraordinarily rich collection obtained in 1884, at depths between 115 and 145 metres, in the artesian boring at Karikal, which is at present being described by Mr. Cossmann in the " Journal de Conchyliologie" (Vol. XLVIII, 1900, p. 14; Vol. LI, 1903, p. 105.)[1]

In Mr Bose's collection, the only recognisable forms are a species of foraminifer, and the abovementioned oyster. The Foraminifera have been studied by Mr. Tipper, who identified them (*Rec. G. S. I.*, XXXIV, p. 135) as *Rotalia Beccarii*, Linn., an indifferent species from a stratigraphical point of view. The oyster, as explained in the previous note, resembles a species from the uppermost Gáj of Sind.

Most of the artesian wells that have been sunk along the eastern coast of the peninsula, in the Madras Presidency or in the included French territories, have penetrated to a certain depth into strata regarded as belonging to the Cuddalore series. Almost every boring record mentions strata crowded with fragmentary shells, but in one instance only, at Karikal, have fossils been obtained in profusion, and in an astonishingly perfect state of preservation. The fauna from the Karikal boring is by a long way the richest tertiary fauna yet discovered in India. The forms so far described by Cossmann are those belonging to the Opisthobranchiata and to the Prosobranchiate families Terebridæ, Pleurotomidæ, Conidæ, Cancellariidæ, Olividæ, Marginellidæ, Mitridæ, Fusidæ, Turbinellidæ, Buccinidæ, Nassidæ, Columbellidæ Muricidæ, Tritonidæ, Cassididæ, Doliidæ, Strombidæ. They include 101 species, while the total number of species from these same groups in the Miocene fauna of Burma only reaches 54, and only 43 in the fauna from the Ranikot of Sind, whose description by Messrs. Cossmann and Pissarro will

[1] The title of the Memoir is "Faune pliocenique de Karikal." Cossmann has correlated the Karikal fauna with that described by Martin in Java, which has often been regarded as upper miocene or pliocene. H. Douvillé has shown, (1905), Les Foraminifères dans le Tertiaire de Bornéo (*Bull. S. G. F.*, Vol. V, (4), p. 435) that the Java beds should be regarded as somewhat older. The contradiction is, however, merely apparent, and only a matter of terminology. It was Jenkins in 1864 (J. G. S., XX, p. 445) who first compared the Java beds with those now distinguished as the Gáj series in Kachh and in Sind, and assigned to them an *upper* miocene age. At that time, the term " oligocene " was not in use, and the beds are spoken of as "upper miocene", in opposition to the age of the beds with *Nummulites intermedius*, now constituting the oligocene, but mentioned by Jenkins as "lower miocene."

shortly appear in the Palæontologia Indica. A few families, such as the Volutidæ and Cypræidæ, are omitted from the description of the Karikal fauna, perhaps because they are not represented, in which case the species representing these families in the Burma and Ranikot faunas should be added to the above totals in order to compare their relative richness. Even then the figures for the Burma miocene and Sind Ranikot only rise to 61 and 52 respectively.

In the Karikal fauna, no less than sixteen species are identical with forms from the Miocene (probably Burdigalian) beds of Java described by Martin. Thirty-five are regarded by Cossmann as certainly identical with recent species, five more as doubtfully so. According to various ways of reckoning, Noetling and Martin have considered that the proportion of living species, in the miocene faunas of Burma and Java, is respectively 30 to 48 per cent. for Burma, and 35 to 50 per cent. for Java. The Karikal fauna contains therefore the same percentage of recent forms as the miocene faunas of Burma and Java, both of which are regarded as Burdigalian. So far as it goes, the solitary evidence furnished by the Mayurbhanj *Ostrea* is in complete accordance with this result, as the stratigraphical horizon of a closely related form in Sind is at the limit of the Aquitanian and Burdigalian.

These results are certainly definite enough, but they would acquire far more weight were we better acquainted with the stratigraphy of the Cuddalore series in such a way as to feel sure that the Cuddalore sandstone and the Karikal beds, as well as the Mayurbhanj ones, really belong to the same stratigraphical series. As it is, we are not certain whether the strata intervening between the upper cretaceous sediments and the pleistocene laterite include one or more series.

In the case of General Cullen's collection from the Quilon beds, the forms regarded by Dr. Carter as identical with Sind or Kachh species all belong to the Gáj series. They also indicate, therefore, an age not very different from uppermost Aquitanian.

In conclusion, it may be stated that the evidence so far available everywhere points to the Burdigalian as the most probable age of the Cuddalore series. It is to be hoped that something more definite than is known at present may soon be learnt about this vast formation, which promises to be one of the most interesting in the geology of India.

[E. W. VREDENBURG.]

Note on the quarrying of corundum (mawshinrut) in the N. W. Khasi Hills.

Corundum is found at three places :—(1) Patarknang, a village jointly belonging to Mariaw and Rambrai states, lying a few miles west of the Raoiang

(Riwiang) river; (2) at Nongmaweit village; (3) on the Riandu river, a tributary of the Someshveri river ; but it is said to extend over a very large area near (2) and (3). The stone at (1) is coarse and is regarded by the people as of small value : (2) and (3) are close together and are situated, a few miles west of the U Blay river near its source. They are in the Nongstoin State and produce a superior stone. Corundum is quarried chiefly at (2), a bare hillside, because it occurs there in small lumps a few seers in weight which can be handled easily. The method is to excavate small holes, at most 5 feet deep by 3 in circumference, and to take out any stones which may be found. If nothing is found the hole is abandoned and another dug. The people possess no means of cutting this hard stone and so must perforce leave anything large found. At (3) corundum occurs close to and in the river bed in much larger blocks, weighing probably several tons. It is here that the best quality of stone is found. It is close grained and highly crystalline. It is, however, not worked to any considerable extent owing to the difficulty in cutting it.

The corundum gems—rubies and sapphires—should be found here, probably in the loose clay and sand of the neighbourhood. During the short time I was able to give to examination of the place, however, I found no traces of gems. The place should be worth further examination.

The neighbourhood of (2) and (3) is very difficult of access, (1) less so. I timed my visit in February and gave long notice, so that paths and bridges over the swamps, which would be otherwise great obstacles to passage, could be constructed. The U Blay at this point is a particularly swampy river. Nongmaweit is approximately 26 miles N. W. from Nongstoin, the capital of the state of that name. Its height is approximately 3,400 feet above mean sea-level. The people round Nongmaweit are of the Nongtarei tribe, a small sub-tribe intermediate between the Khasi people proper and the Lyngams of the lower country. They have particularly aquiline features for hill men.

The corundum extracted from (2) is taken to Nongstoin village for sale, thence it finds its way all over the hills for sale as hones.

[F. E. JACKSON],
Deputy Commissioner, Khasi and Jaintia Hills.

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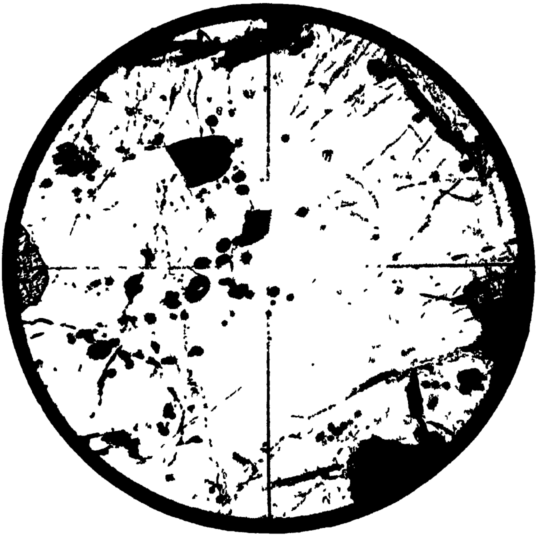

FIG 1

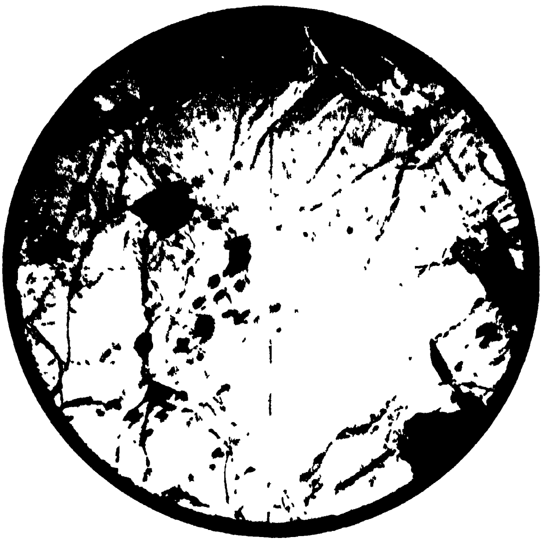

FIG 2.

Microphoto by T. L. Walker

SAPPHIRINE- AND SPINEL-BEARING ROCKS OF VIZAGAPATAM

Fig. 1

Fig. 2

[illegible] Walker

[illegible]

SAPPHIRINE- AND SPINEL-BEARING ROCKS OF VIZAGAPATAM

FIG 1

FIG 2

Microphoto by T. L. Walker

Bemrose, Collo., Derby

SAPPHIRINE- AND SPINEL-BEARING ROCKS OF VIZAGAPATAM

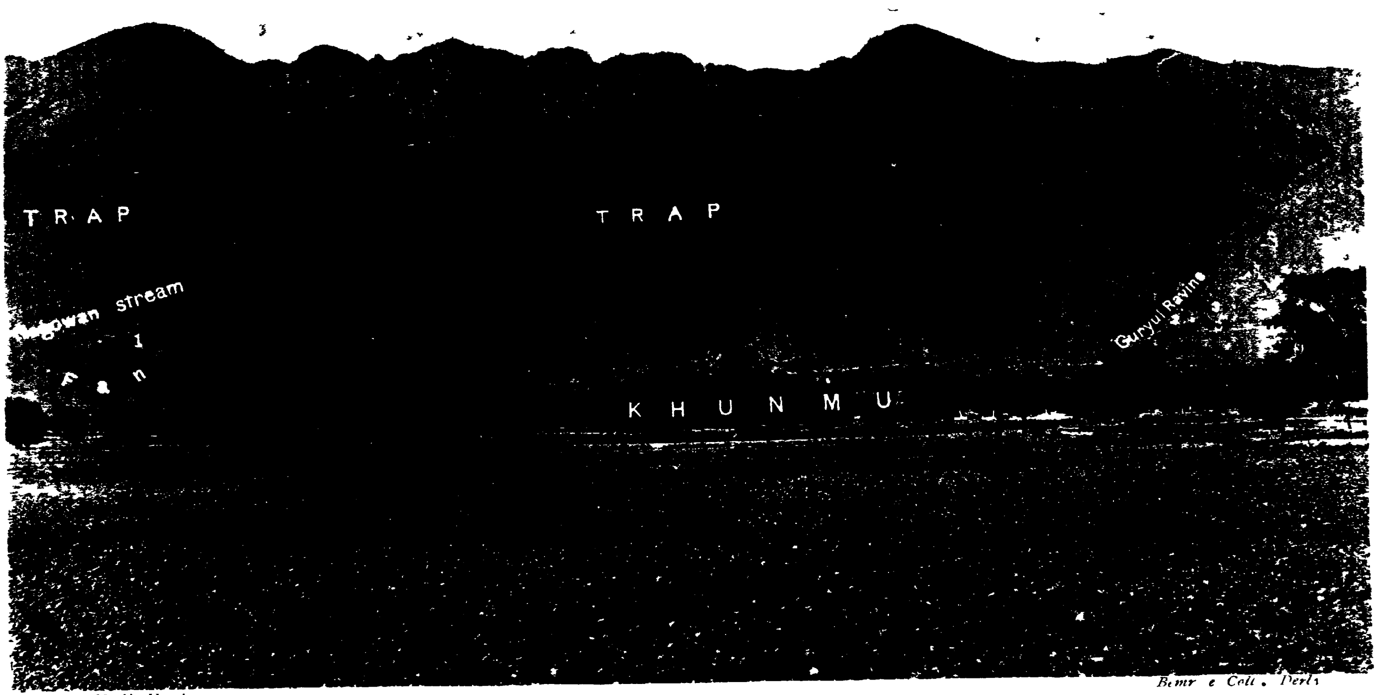

Photo by H H Hayden

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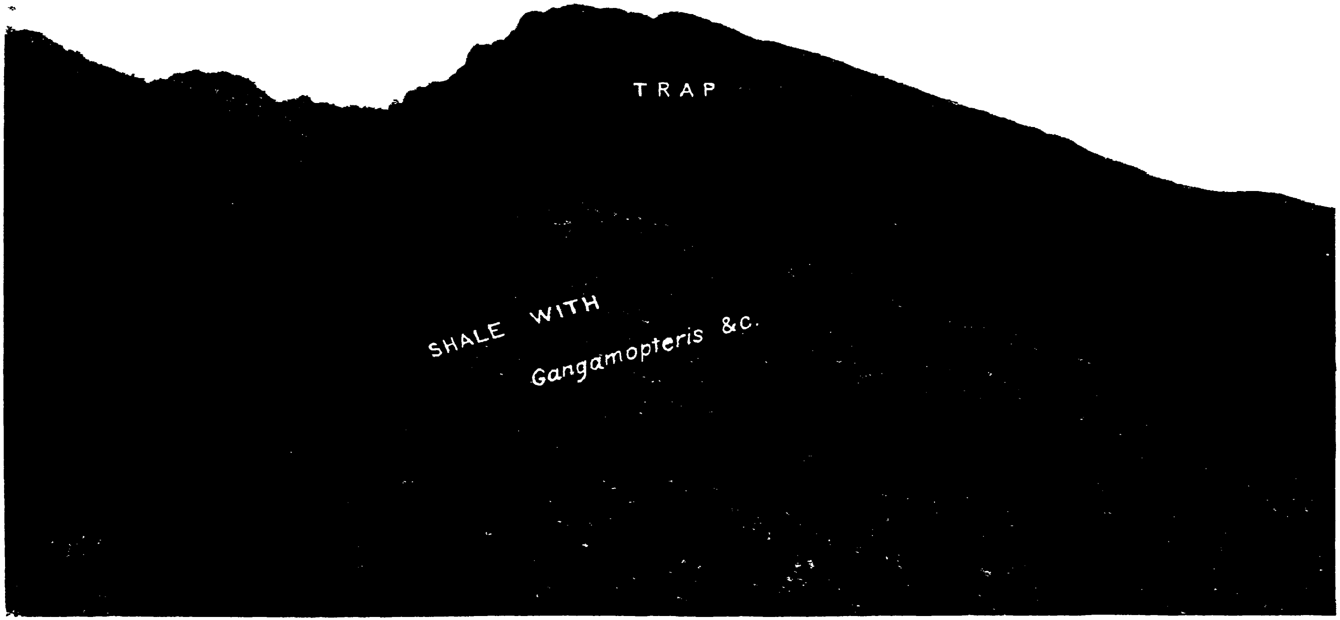
HILLS NORTH-WEST OF KHUNMU



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FRONT VIEW OF GANGAMOPTERIS BEDS KHUNMU

Dr N ethn, origin a th.

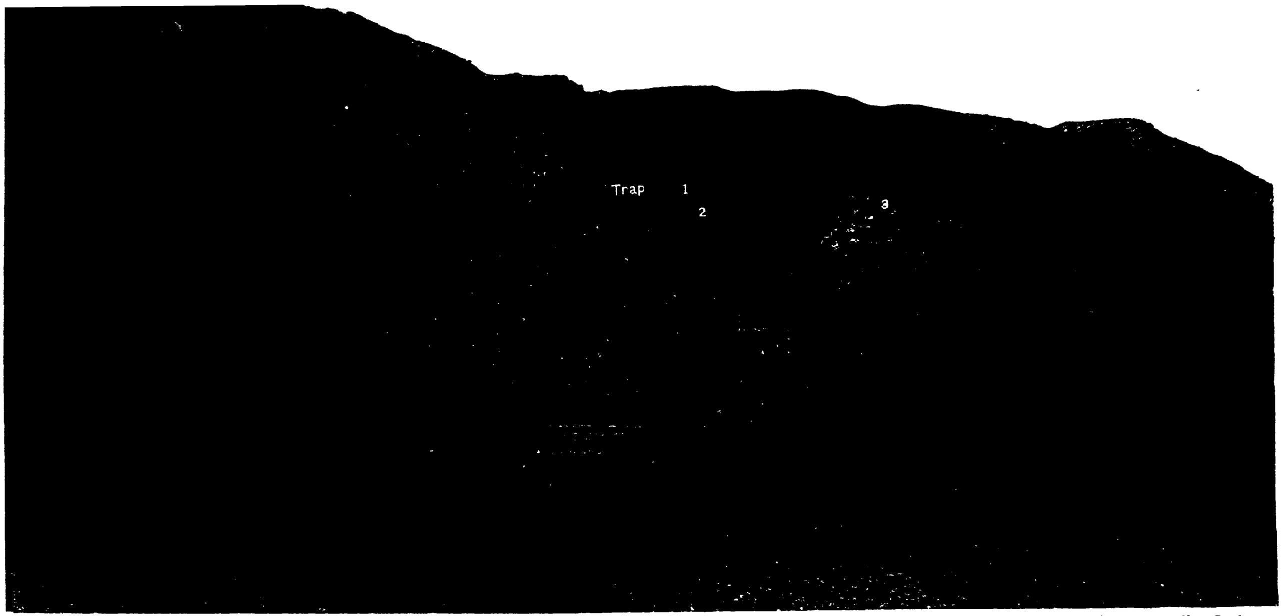


Photo. by H. H. Hayden.

RIDGE NEAR ZEWAN. VIHI (KASHMIR).

Bemrose, Collo., Derby

FIG 1

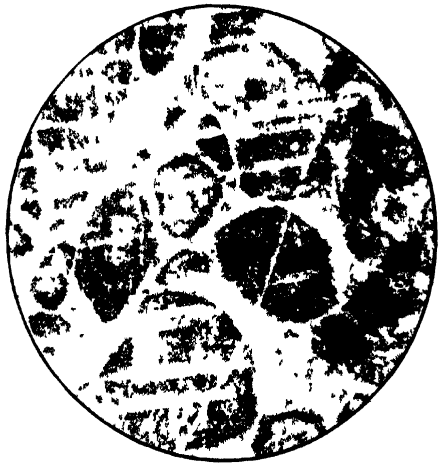


FIG 2

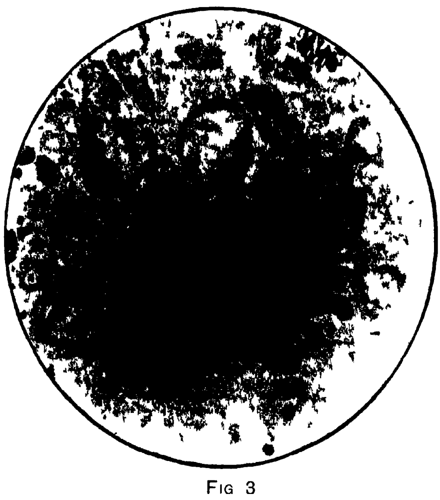


FIG 3

FIG 4

Microphot by H H Hayden

Bemrose Collo Derby

LIMESTONES AND CHERTS OF VIHI KASHMIR

FIG. 1.

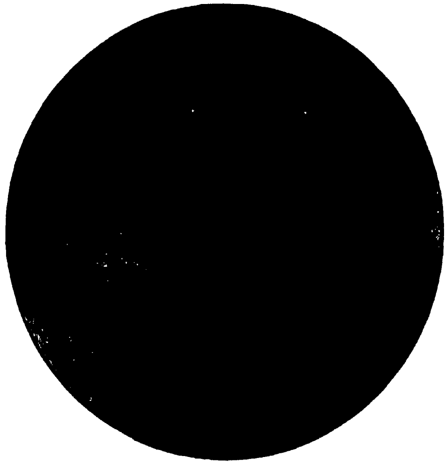


FIG. 2.

FIG 3.

FIG. 4.

Microphoto. by H. H. Hayden.

Bemrose, Collo., Derby.

LIMESTONES AND NOVACULITES OF VIHI, KASHMIR.

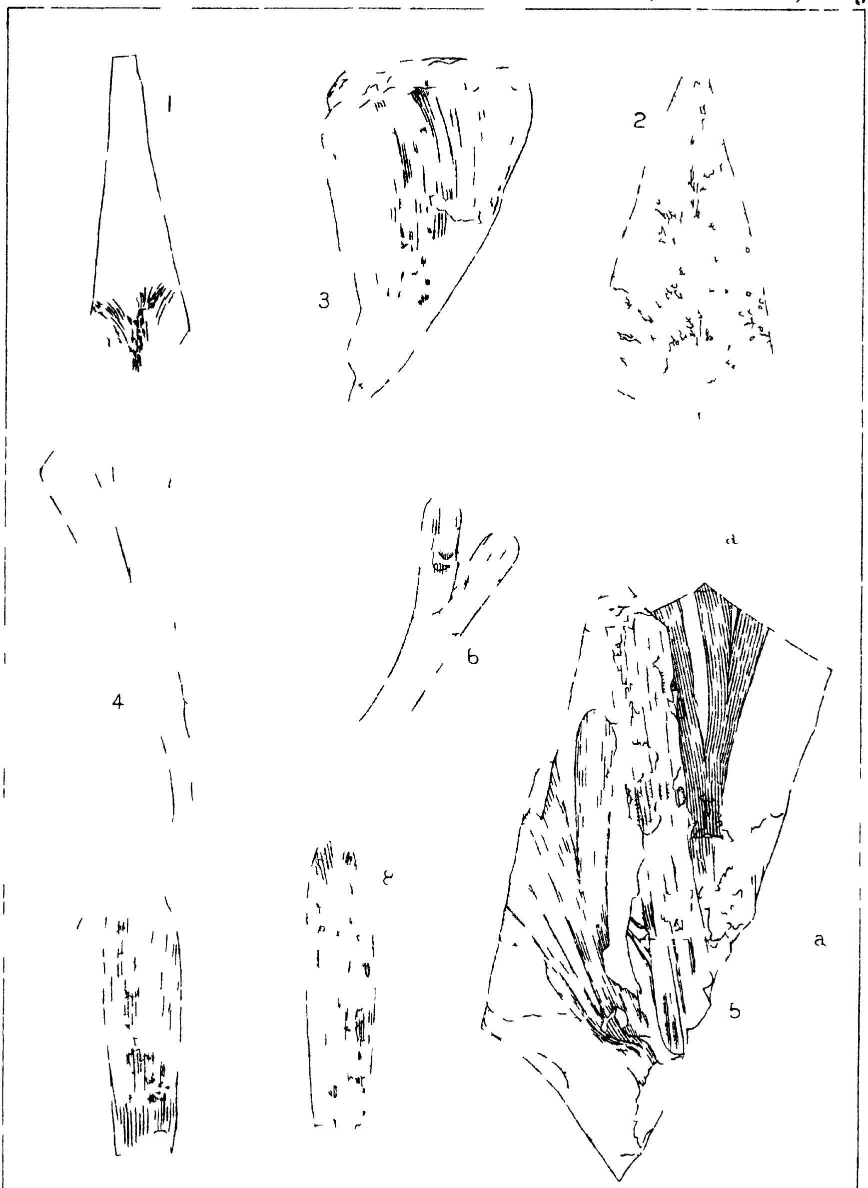
BASALT DYKE. N SIDE OF LOI HAN HUN̈

COLUMNAR BASALT SUMMIT OF LOI HAN HUN

C. M. Woodward del.

NEW SUIDAE FROM THE BUGTI HILLS BALUCHISTAN

ALL FIGURES NATURAL SIZE



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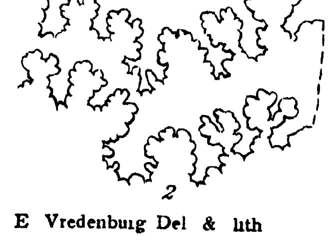
GANGAMOPTERIS PSYGMOPHYLLUM CORDAITES

1



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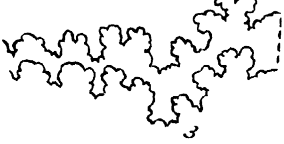

3

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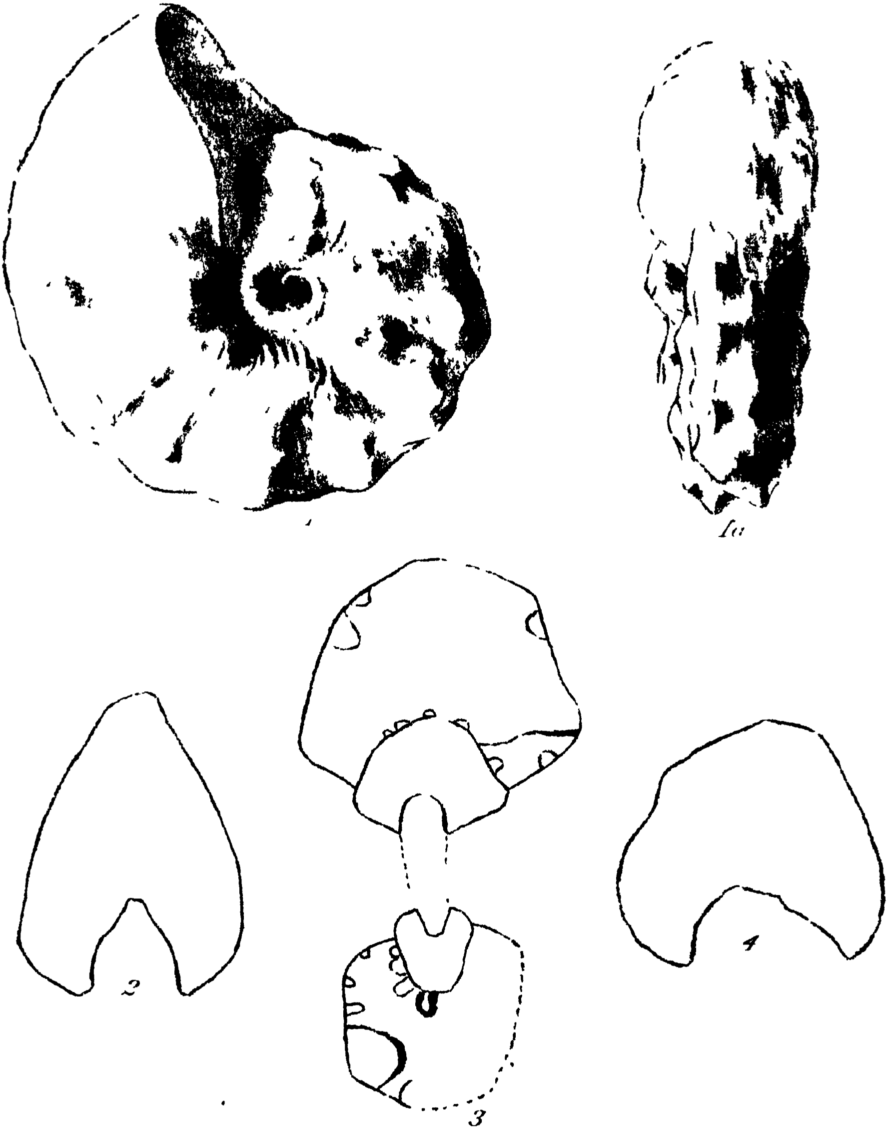
Placenticeras Mintoi, nov spec



E. Vredenburg Del. &. lith

Placenticeras Mintoi, nov. spec.

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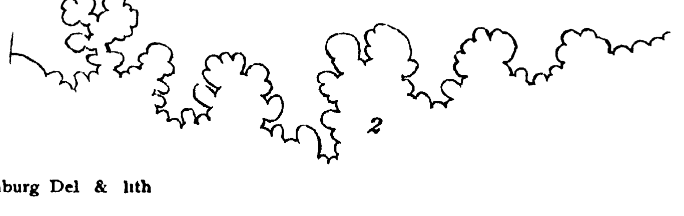

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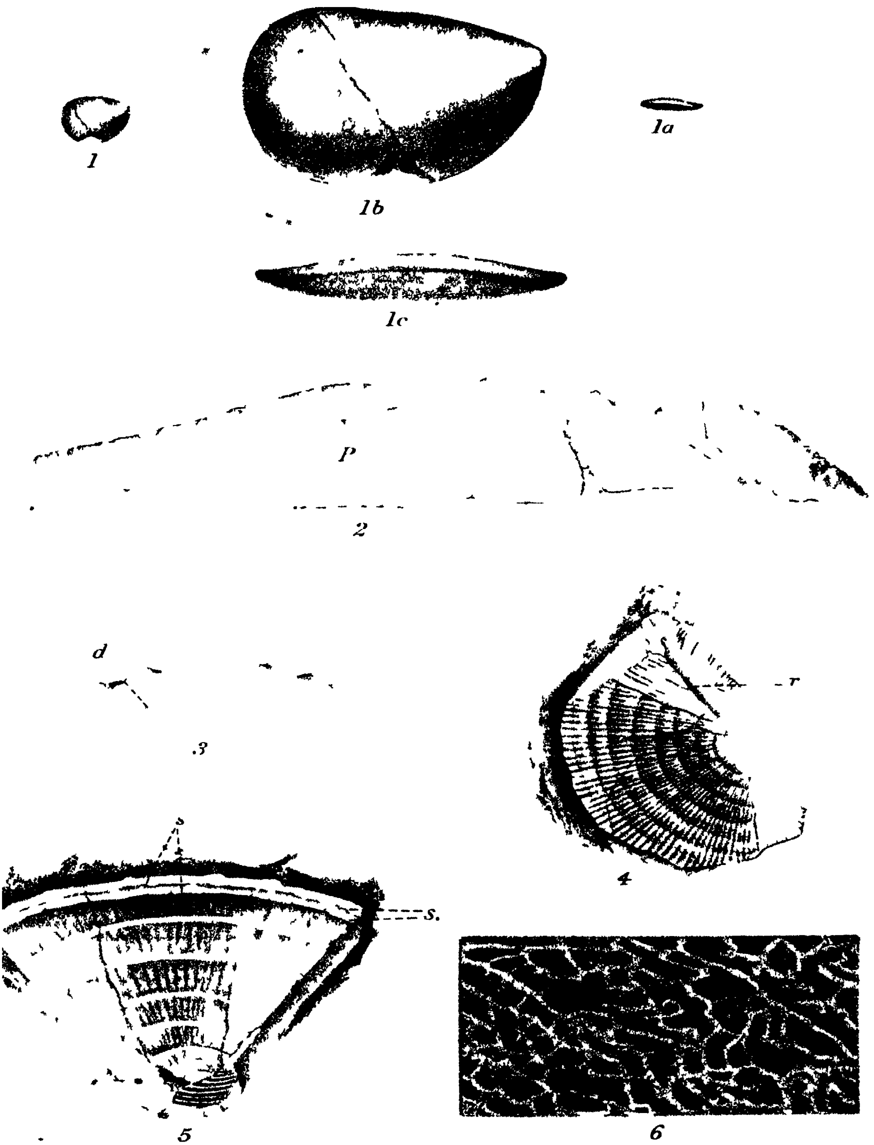
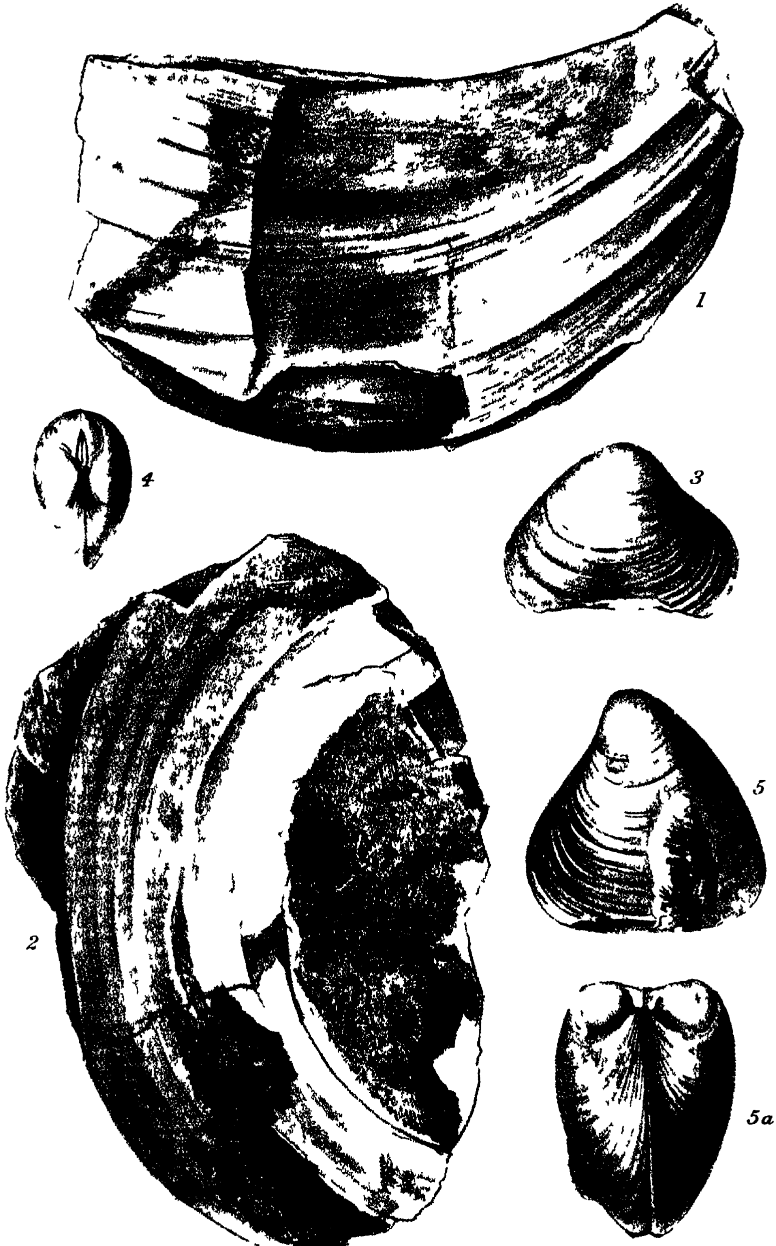
Namadoceras Scindiæ, nov. spec.

E. Vredenburg Del & lith

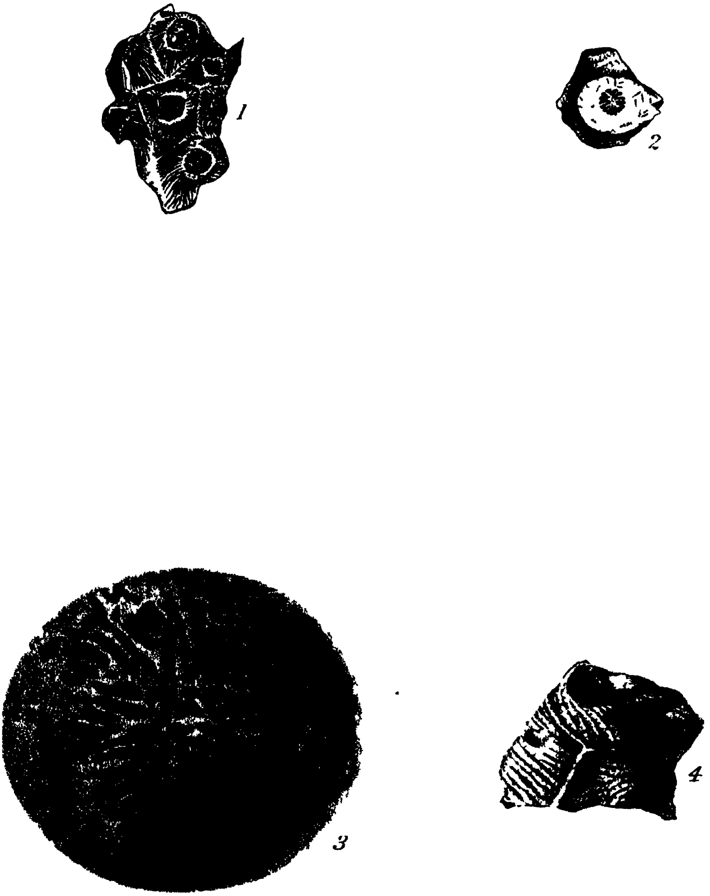
Namadoceras Bosei, nov. sp.



"TWINGONIA"



BATISSA KODAUNGENSIS, B. CRAWFURDI *var* YEDWINENSIS.



E. H. Pascoe and G. de P. Cotter.

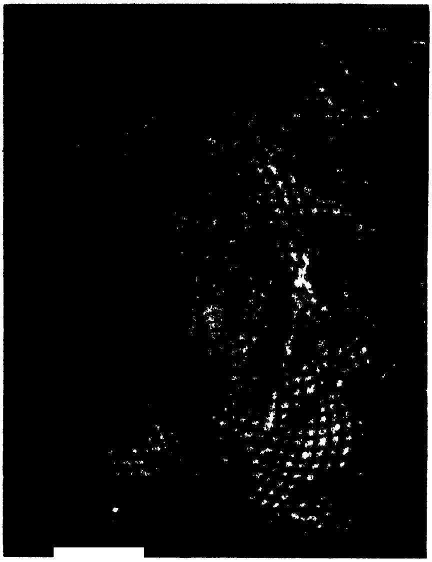
DENDROPHYLLIA MACRORIANA. N. SP.

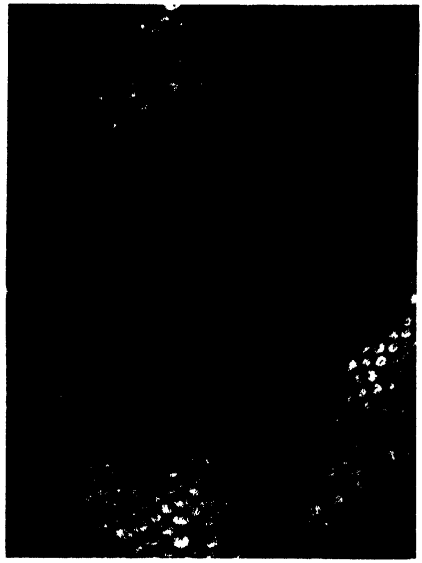
G. de P Cotter Photo. Bemrose Collo, Derby

SECTION IN THE TAUNGTHA STREAM-BED SHOWING FAULTED STRATA.

Phototypie M Jaffe, Vienna

Fossils from Arabia.





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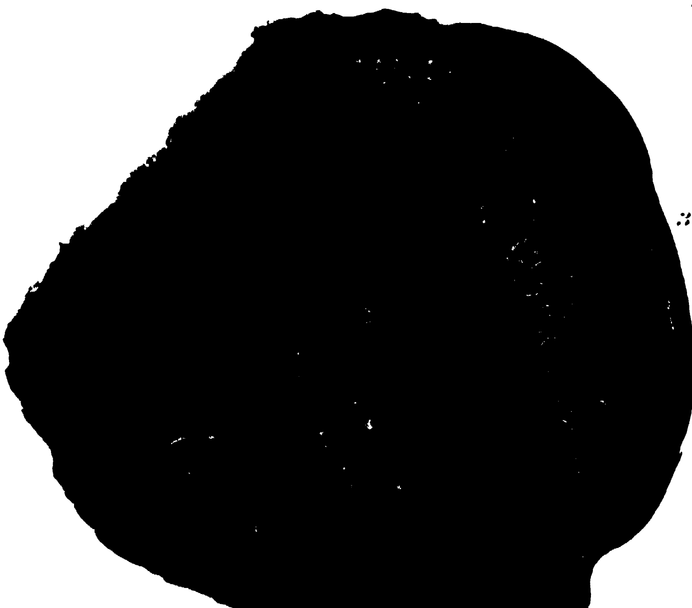
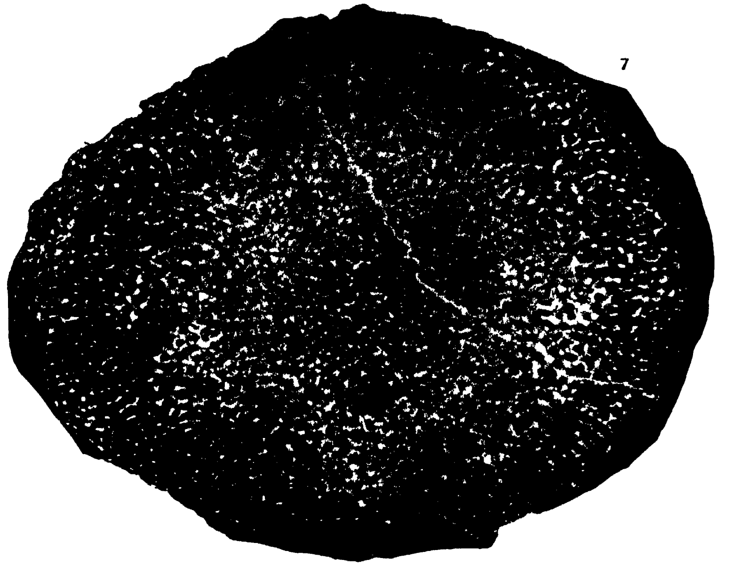


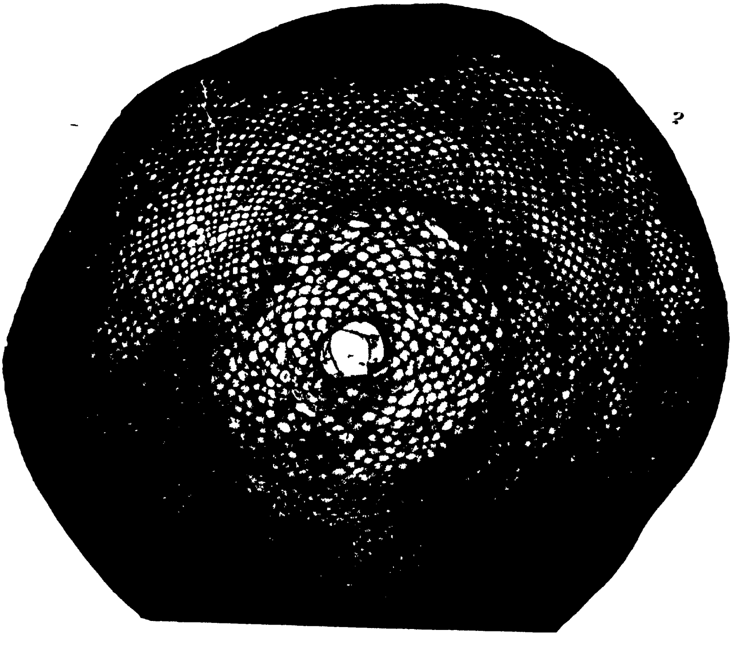
3

Orbitoides media, d'Archiac
1, megaspheric · 2, microspheric
3 lateral layers

Photo. by E. W. Vredenburg.

Bemrose, Collo., Derby.





Orbitoides Hollandi n. sp

Photo. by E. W Vredenburg.

Bemrose, Collo., Derby.

1

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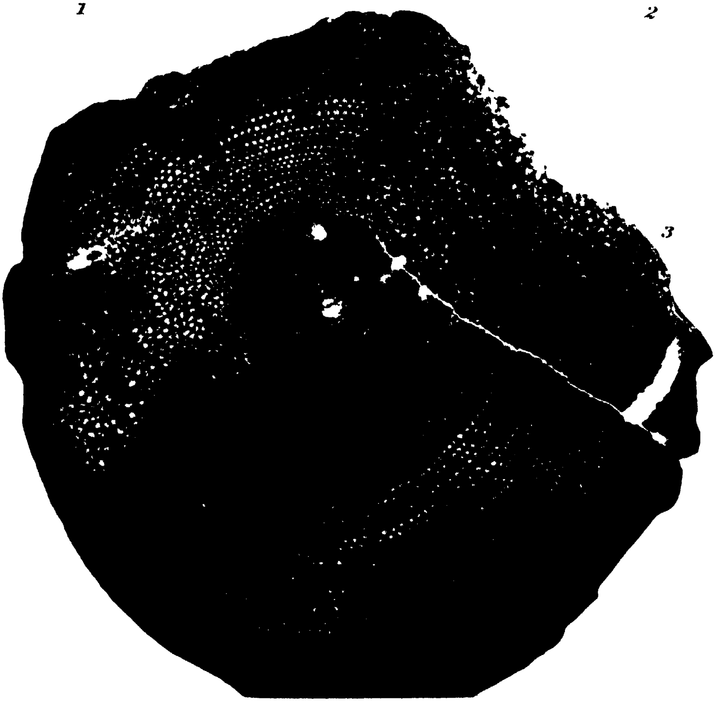
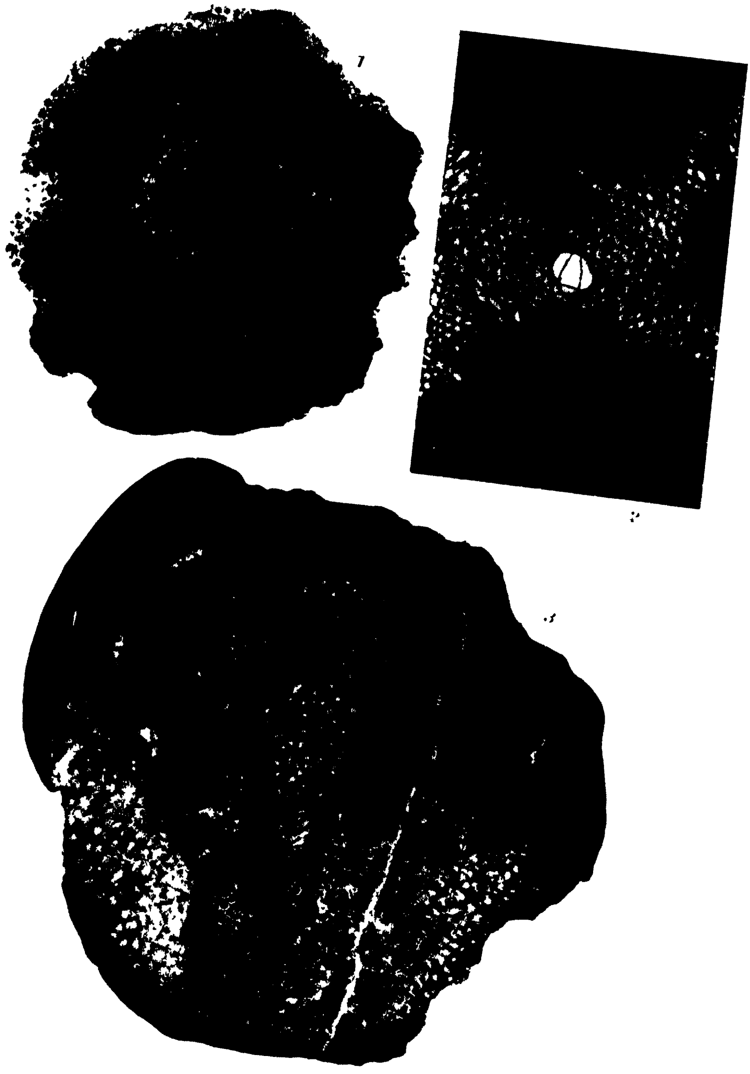


3

Orbitoides socialis, Leymerie
1, lateral layers. 2, Equatorial layer
3 Specimen from the Pyrenees

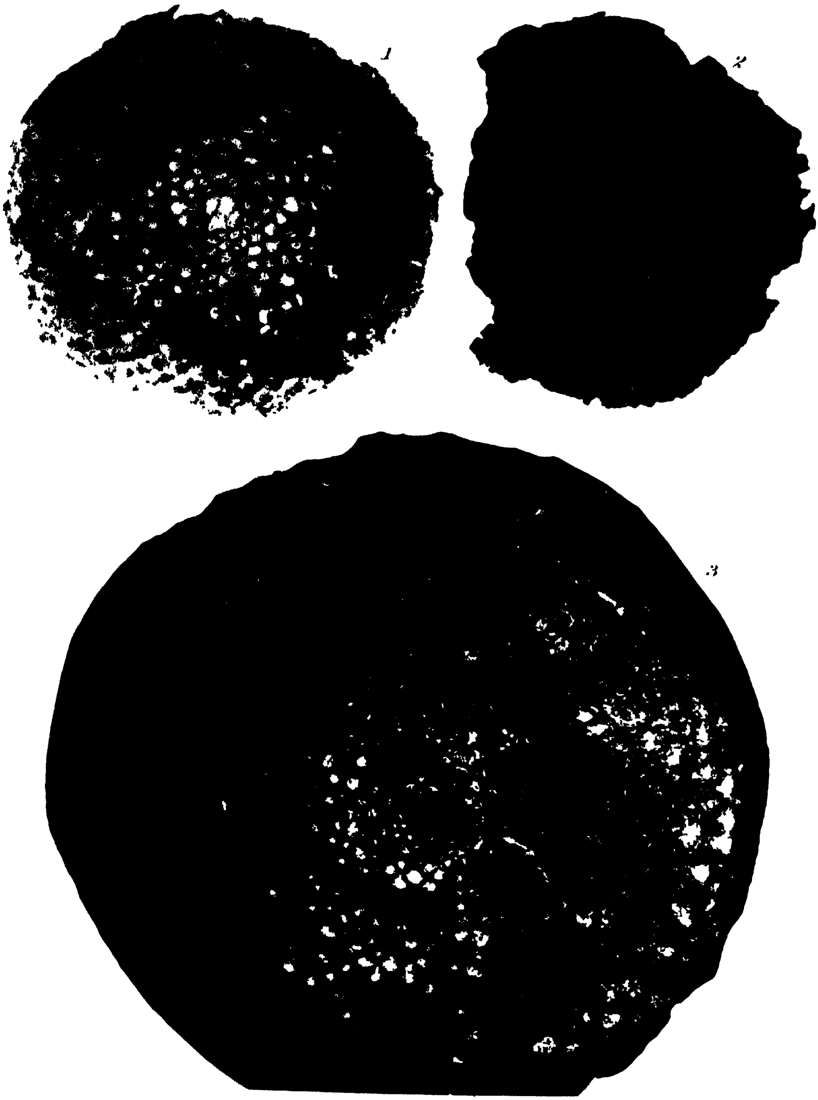
Photo. by E. W. Vredenburg. Bemrose, Collo., Derby.



1 *Orbitoides minor*, Schlumberger 2 *Orbitoides media* d'Archiac
3 *Orbitoides apiculata* Schlumberger

Photo by F W Vredenburg

Bemrose, Collo Derby.



Omphalocyclus macropora Lamarck
1. 2. megaspheric. 3. microspheric.

Photo. by E. W. Vredenburg.

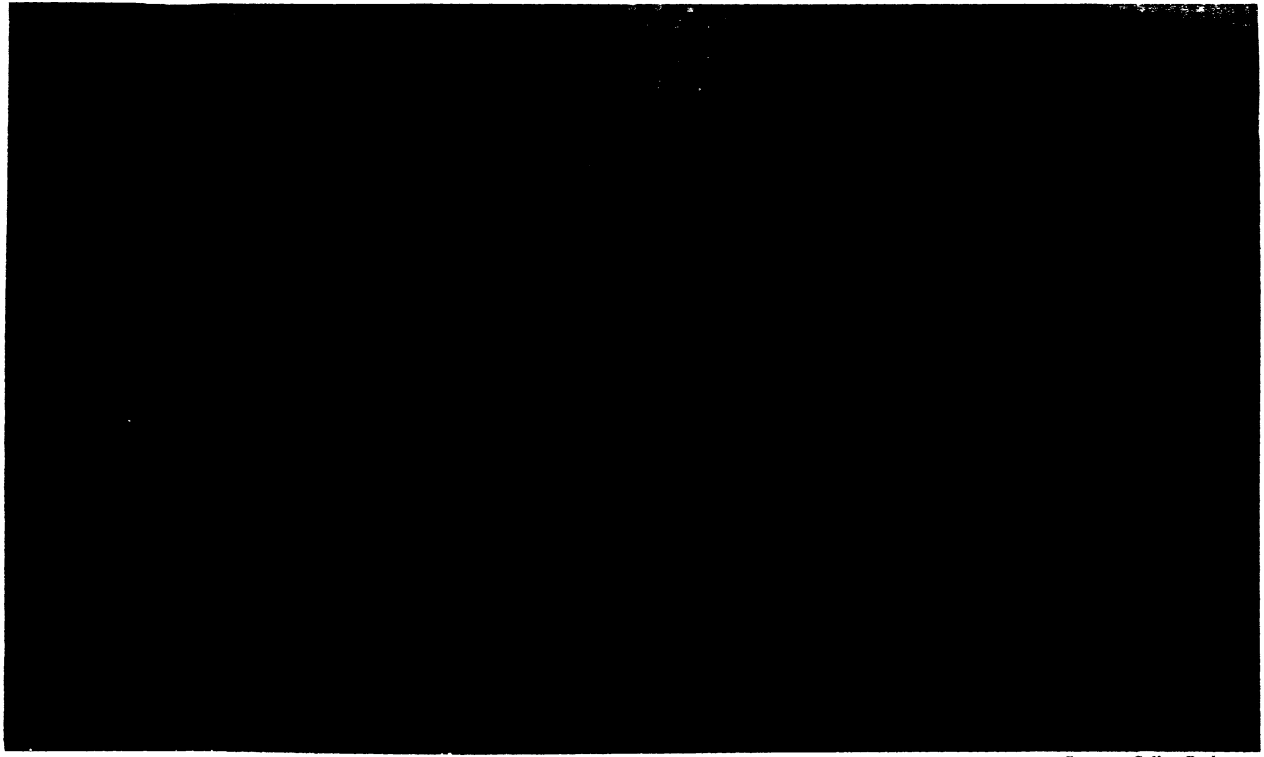
Bemrose, Collo, Derby.

Photographed by L W Vredenburg — *Bemrose Collo Derby*

FOSSIL FRUIT AND CRETACEOUS FLYSCH FOSSILS FROM FORT MUNRO

Photographed by E W Vredenburg — *Bemrose Collo., Derby*

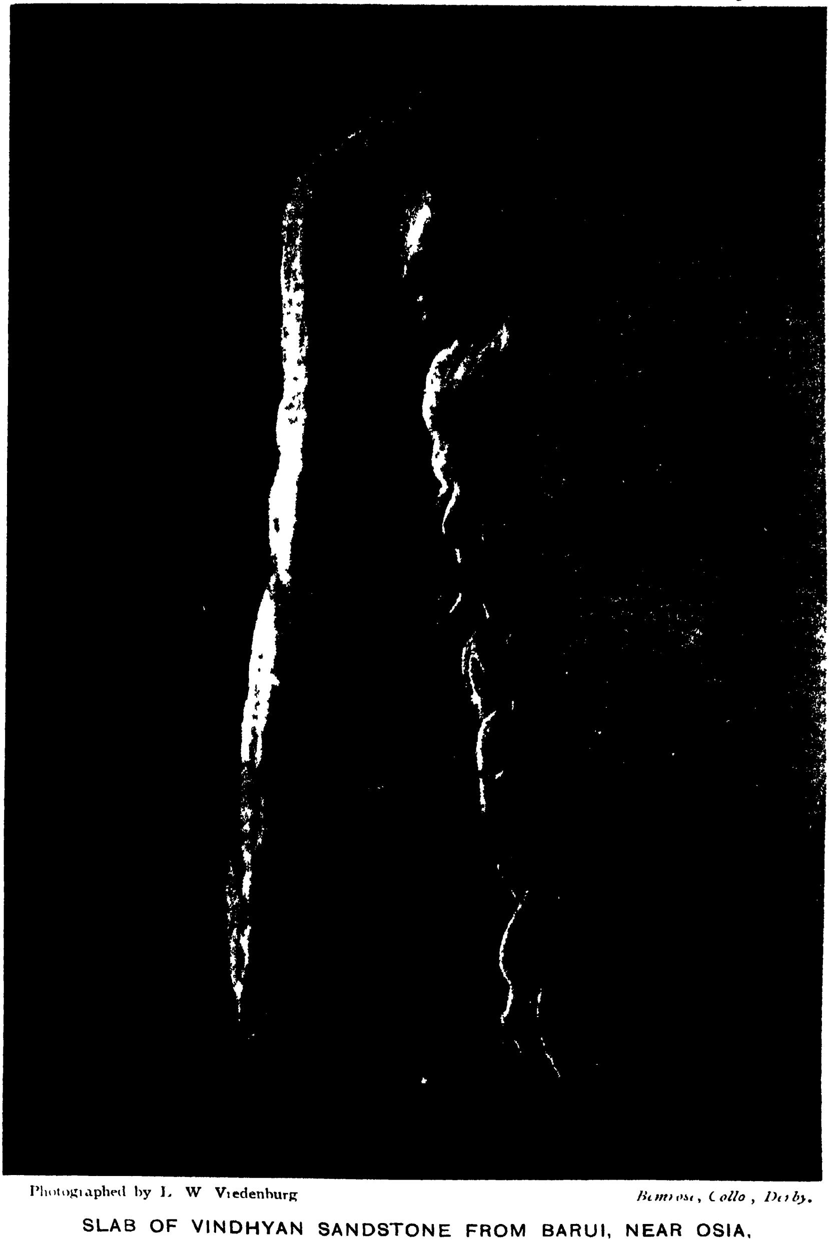
SLABS OF SANDSTONE FROM THE CRETACEOUS FLYSCH OF FORT MUNRO



Photographed by E. W. Vredenburg

Bemrose, Collo., Derby.

SLAB OF VINDHYAN SANDSTONE FROM LILGAR, BHOPAL STATE (CENTRAL INDIA).



Photographed by L. W. Viedenburg | *Bemrose, Collo., Derby.*

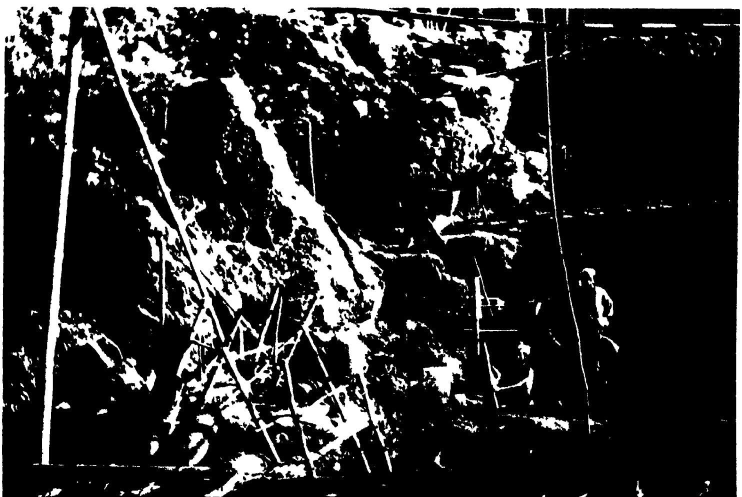
SLAB OF VINDHYAN SANDSTONE FROM BARUI, NEAR OSIA, JODHPUR STATE (RAJPUTANA).

GENERAL VIEW OF THE JADE-MINES, TAWMAW.

Photographed by A. W. G. Bleeck. *Bemrose, Collo., Derby*

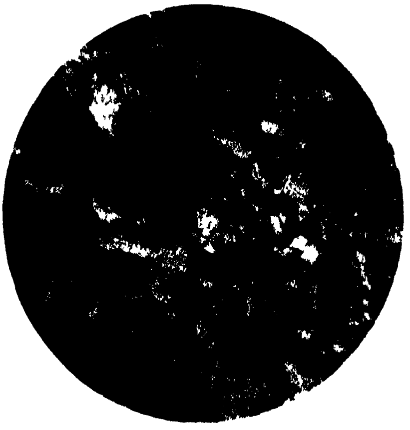
A WORKED-OUT PORTION OF THE JADEITE-ALBITE DYKE AT TAWMAW.

KACHINS TRANSPORTING A BOULDER OF JADEITE, HWÉKA



Photographed by A. W. G. Bleeck | Bemrose Collo., Derby

QUARRYING AT HWÉKA



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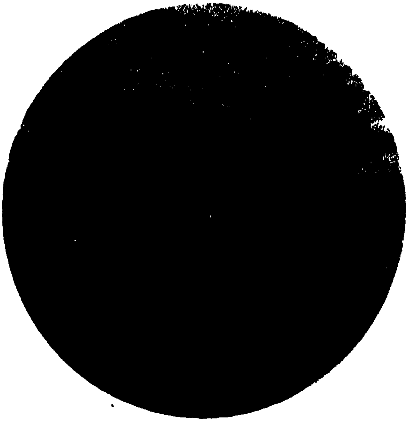
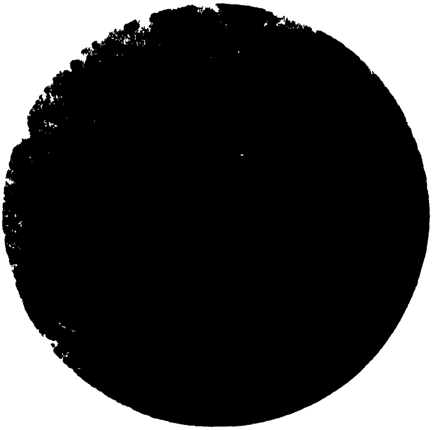


4

Photographed by A. W. G Bleeck.

Bemrose, Collo., Derby.

JADEITE DEPOSITS OF UPPER BURMA.



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Photographed by A W G Bleeck

Bemrose Collo, Derby

JADEITE DEPOSITS OF UPPER BURMA

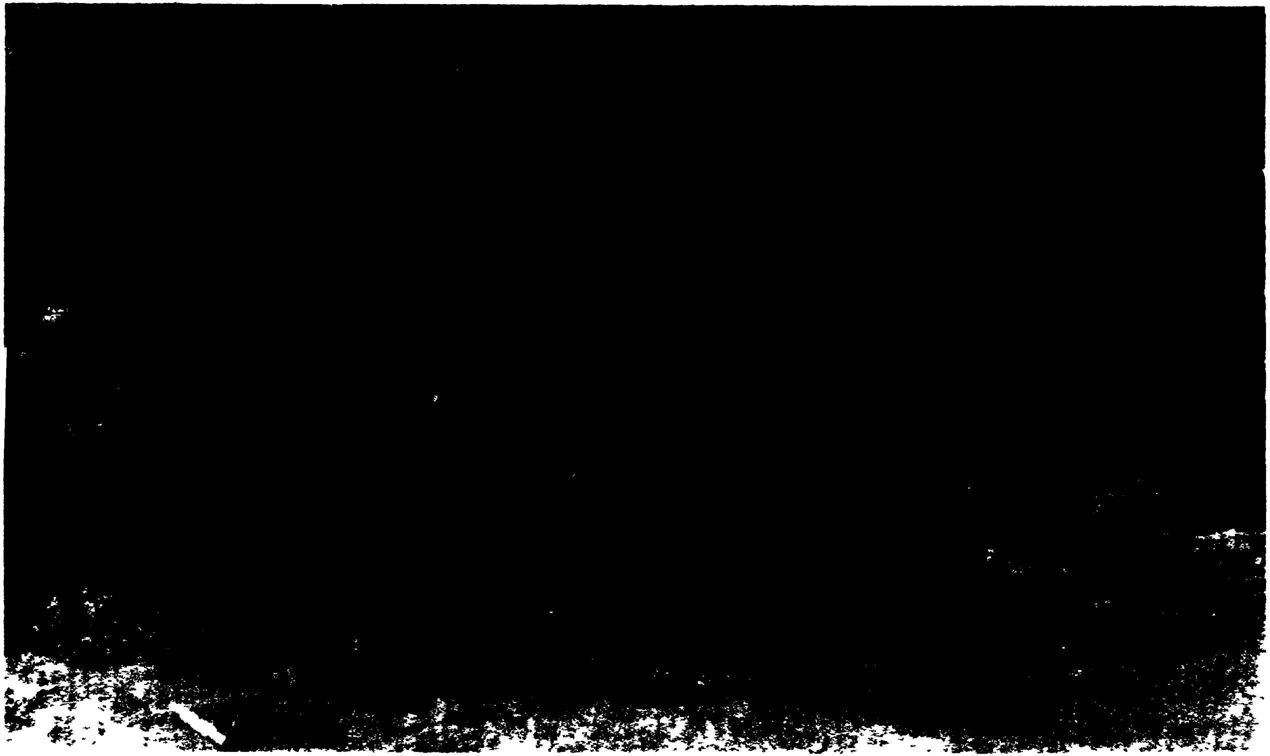
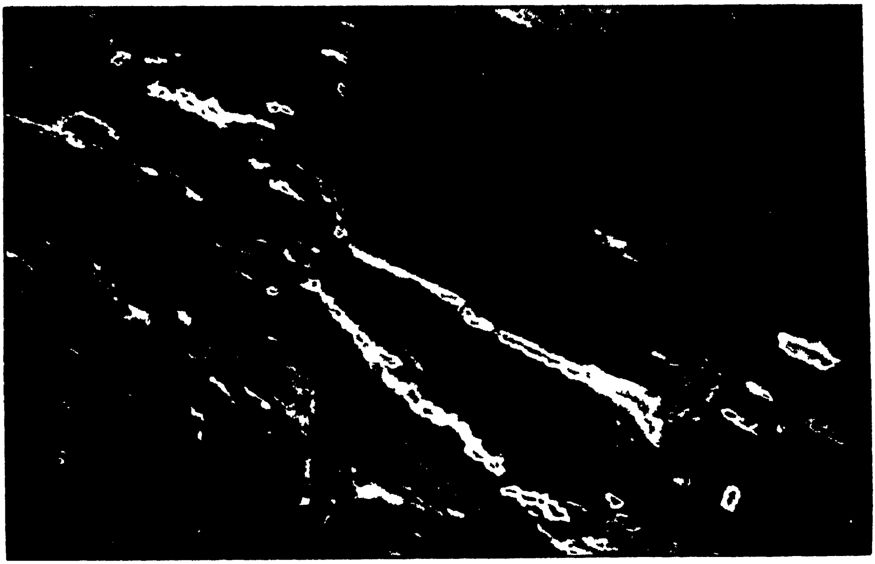


Photo by E. H. Pascoe.

Bemrose, Collo., Derby.

LOCAL CONTORTION AND UNCONFORMITY IN THE MIOCENE, YEDWET CHAUNG.



EFFLORESCENCE OF ALUM AT MORMUGAO

Date of issue.	Date of issue.	Date of issue.
23.11.50		
29-3-66		